CHAPTER 21

Gesturing across the Life Span

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SITUATING GESTURE IN RELATION TO NONVERBAL BEHAVIOR AND SIGN LANGUAGE

People move their hands when they talk—they gesture—and they do so at every stage of the life span. Some people gesture more than others, but everyone gestures. The question is why? Everyone's first guess is that gesture is nothing more than hand waving, something that we do when we are nervous or excited, but that has no purpose. But this guess turns out to be wrong. Gesturing plays an important role in how we communicate and also how we think. This chapter explores both roles.

Gesture has been an object of attention for at least 2,000 years, across domains as diverse as philosophy, rhetoric, theater, divinity, and language. It came into modern-day focus, this time in the semiotic world, as one of five nonverbal behaviors catalogued by Ekman and Friesen in 1969. The five behaviors are distinguished along a number of dimensions, the most important of which for our purposes is the behavior's connection to speech. Four of the nonverbal behaviors can be produced with speech, but need not be. The fifth—gesture—is tied to speech.

The first nonverbal behavior listed by Ekman and Friesen (1969) is the *affect display,* whose primary site is the face. Affect displays convey emotions whether or not the person is talking. The second nonverbal behavior is the *regulator,* which typically involves head movements or slight changes in body position. Regulators maintain the give-and-take between individuals when talking, but also when not talking. The third nonverbal behavior, the *adaptor,* is a fragment or reduction of a previously learned adaptive hand movement maintained by habit (e.g., pushing one's glasses up when the glasses are already perfectly positioned). Adaptors are performed with little awareness and no intent to communicate. They can be used at any time. The fourth behavior, the *emblem*, is what typically comes to mind when people say they are talking about gesture. Emblems have conventional forms and meanings, and therefore vary across cultures. For example, the *thumbs-up*, the *okay*, and the *shush* gestures are all immediately recognizable in American culture. We are always aware of having produced an emblem, and we use them to communicate, often to control someone else's behavior. But emblems need not be produced with speech. Indeed, one of their defining features is that they are interpretable on their own without speech.

The last category, called *illustrators*, in Ekman and Friesen's (1969) classification scheme, is, by definition, tied to speech and often illustrates the speech it accompanies. For example, a child says that one container is taller than another and illustrates the point by indicating with her hand first the height of one container and then the height of the other. This chapter focuses on illustrators, called *gesticulation* by Kendon (1980) and plain old *gesture* by McNeill (1992), the term we will use. Gestures can mark the tempo of speech (beat gestures), point out referents of speech (deictic gestures), or exploit imagery to elaborate the contents of speech (iconic or metaphoric gestures). In every case, gesture has some relation to the speech it accompanies (although, as we will see, the relation need not be a redundant one). Gesture is not only tied to speech semantically but also temporally. Gesture and speech are integrated into a single system serving the functions of communication (Goldin-Meadow, 2003; McNeill, 1992).

Although gestures share the burden of communication with the speech they accompany, they are different from speech. They convey meaning but do so only in conjunction with the words that frame them. They do not need to, and indeed cannot, stand on their own. As a result, there is no need for the form of a gesture to be standardized, and it is, unlike speech, created on the fly to capture the meaning of the moment.

Gesture is also very different from sign languages of the deaf, despite the fact that both are produced in the manual modality. Sign languages are autonomous systems that are not based on the spoken languages of the hearing cultures that surround them (Bellugi & Studdert-Kennedy, 1980; Klima & Bellugi, 1979; Lane & Grosjean, 1980). The structure of American Sign Language, for example, is distinct from the structure of English. Indeed, the structure of *American* Sign Language is distinct from the structure of *British* Sign Language, a comparison that dramatically underscores the point that sign languages are not derivative from spoken languages. Nevertheless, sign languages are structurally similar to spoken languages and, as such, different from gesture.

For example, lexical items in a sign language, like all languages, have a right and a wrong form. The sign for "candy" in American Sign Language is made by rotating the tip of the index finger on the cheek. A signer cannot arbitrarily choose to, say, rotate the knuckle of her index finger on her cheek to mean "candy." In fact, if she does use her knuckle, she produces the sign for "apple." If she uses her middle finger instead of her index finger, she produces no sign at all. It is easy to produce a sign incorrectly, but it is not even clear what it means to talk about producing a gesture incorrectly. For example, three speakers described Sylvester the cat's ascent up a drainpipe and used different gestures along with their verbal descriptions. The first flicked a flat palm upward to denote the ascent. The second wiggled the two fingers of a V hand shape as he moved his hand upward. The third produced a basket-like hand shape and moved it upward (McNeill, 1992, pp. 125–126). Each of the three speakers used a different hand shape (palm, V, basket-like shape)—clearly, there is more than one way to represent a cat in gesture.

The fact that gesture plays a role in communication but is not itself codified is precisely why it is of interest to us. Gesture is free to take on forms and meanings that are not dictated by a shared linguistic code. It, therefore, has the potential to tell us about thoughts that do not fit neatly into categories established by our language (Goldin-Meadow & McNeill, 1999). This chapter begins by providing evidence that gesture takes advantage of this potential, often conveying information that is not found in a speaker's words.

We then explore the role of gesture in communication over the life span. If the information conveyed in gesture is accessible to listeners, even those not trained in gesture coding, then gesture adds a second track to every conversation. There is now compelling evidence that this second track has a substantial effect on what speakers and listeners get out of the conversation.

We also explore the role of gesture in cognition over the life span. Gesture conveys information that is not found in speech and, in this sense, reflects a speaker's unspoken thoughts. But evidence is mounting that gesture does more than reflect thought. It can play a role in changing thought and, thus, is a factor in learning.

Our next step is to explore the role of gesture in communication and cognition early in the life span when children are first learning language, and later in the life span when older adults may be losing some of their linguistic skills (e.g., the ability to hear or to deal with complex sentential structures). The question is whether gesture does the same kind of work with respect to communication and cognition throughout the life span.

Finally, we explore what gesture can tell us about developmental disorders and disorders of adulthood. Because gesture is a good index of what a speaker knows, it can also be used to index what a speaker does not know. It, therefore, has the potential to serve as a diagnostic tool in identifying children who are, and who are not, on the road to developmental delay or disability, and perhaps in identifying skills that are spared in adults who have become disabled. Moreover, because gesture can change what we know, it has the potential to serve as an effective tool for intervention for child and adult alike. We end by considering whether gesture plays the same role throughout the life span.

GESTURE IS A WINDOW TO THE MIND

The folk view of nonverbal behavior, including gesture, is that it expresses our emotions and attitudes, and perhaps our personality (see Argyle, 1975). For example, we instinctively believe that gesture marks a speaker as a liar, but it does not give away the content of his lies. The folk view is correct, but only in part. A speaker's hand gestures can, indeed, identify him as a liar (Ekman, Friesen, & Ellsworth, 1972, p. 367). But gesture can also give away the content of the speaker's lies and, of course, his truths. As an example of a truth, a speaker says "I ran all the way upstairs" while spiraling his hand upward. The speaker has conveyed through his gesture, and only through his gesture, that the staircase he mounted was a spiral. Perhaps if his spiral movement were produced slowly and with little enthusiasm, it would also convey the speaker's attitude toward his climb. But at the least, the gesture provides specific information that goes beyond feelings and attitudes.

Gesture Conveys Substantive Information

The gestures that speakers produce together with their talk are symbolic acts that convey meaning. It is easy to overlook the symbolic nature of gesture simply because its encoding is iconic. A gesture looks like what it represents—for example, a shoe-tying motion in the air resembles the action used to tie a shoe—but the gesture is no more the actual act of tying than is the word *tie*.

Because gesture can convey substantive information, it can provide insight into a speaker's mental representation (Kendon, 1980; McNeill, 1992). For example, a speaker in one of McNeill's (1992, p. 12) studies says "and he bends it way back" while his hand appears to grip something and pull it from a space high in front of him back and down to his shoulder. The speaker is describing a scene from a comic book in which a character bends a tree back to the ground. The gesture reveals the particular point of view that the speaker takes to the event—he is gripping the tree as though he were the tree-bender, making it clear by his actions that the tree was anchored on the ground. He could, alternatively, have represented the action from the point of view of the tree, producing the same motion without the grip and perhaps in a different space (one that was not tied to his shoulder), a movement that would have conveyed the tree's trajectory but not the actions done on it.

As an example from a more abstract domain, consider a speaker gesturing about a moral dilemma (Church, Schonert-Reichl, Goodman, Kelly, & Ayman-Nolley, 1995). An adult is asked to judge whether a father has a right to ask his son to give up the money he earned to go camping so that the father can go fishing (Kohlberg, 1969). The adult gives a relatively abstract explanation of his beliefs in speech: "I think about opportunities like this where you have two interests that compete with one another. This is the point where people develop the skills of negotiation." At the same time, he conveys an equally abstract set of ideas in gesture: The speaker holds both hands out in front 6 to 8 inches apart, with the thumb and index finger of each hand resembling an equal sign (illustrating two sets of interests). He then brings his hands in toward one another and holds them in the air (highlighting the fact that the two set of interests are not aligned). Finally, he pivots both wrists in an alternating manner so that while one is forward, the other is back (illustrating how the interests can be brought together in a process of negotiation). This gesture, like the speech that accompanies it, conveys the notion that there are two equal points of view coming into a dynamic interaction with one another.

School-aged children also use hand gestures as they speak (Jancovic, Devoe, & Wiener, 1975), gesturing when asked to narrate a story (e.g., McNeill, 1992) or when asked to explain their responses to a problem (e.g., Church & Goldin-Meadow, 1986). The gestures children produce in a problem-solving situation provide insight into the way they represent those problems. For example, Evans and Rubin (1979) taught children to play a simple board game and then asked them to explain the game to an adult. The children's verbal statements of the rules were routinely accompanied by gestures that conveyed information about their knowledge of the game. As a second example, Crowder and Newman (1993) found that gestures were a frequent mode of communication in a science lesson on the seasons. A child discussing the seasons used both hands to produce a symmetrical gesture, laying down temperature bands on either side of the equator, and thus revealing, through her hands, knowledge of the symmetry of the hemispheres.

Gesture and Speech Form an Integrated System

Gesture not only conveys meaning, it does so in a manner that is integrated with speech. Several types of evidence lend support to the view that gesture and speech form a single, unified system. First, gestures routinely occur with speech. Although emblems may be delivered in utter silence, the spontaneous gestures that speakers generate are almost always produced when the speaker is actually talking. McNeill (1992) found that 90% of gestures were produced during talk. Thus, acts of speaking and gesturing are bound to each other.

Second, gestures and speech are semantically and pragmatically coexpressive. Each type of gesture has a characteristic type of speech with which it occurs (McNeill, 1992). For example, iconic gestures accompany utterances that depict concrete objects and events, and fulfill a narrative function—they accompany the speech that "tells the story." The bend-back gesture described earlier is a concrete description of an event in the story and is a good example of an iconic gesture. In contrast, metaphoric gestures often accompany utterances that refer to the structure of the discourse rather than to a particular event in the narrative. For example, when announcing that what he had just seen and was about to recount was a cartoon, a speaker produced the following metaphoric gesture (McNeill, 1992, p. 14): The speaker raised his hands as though he were offering an object to the listener while saying, "It was a Sylvester and Tweety cartoon," an utterance that sets up and introduces the topic of discussion rather than forming part of the story line.

Finally, gesture and speech are temporally synchronous, and thus form a unified system in this sense. The gesture and the linguistic segment representing the same information as that gesture are cotemporal. Specifically, the gesture movement—the *stroke*—lines up in time with the equivalent linguistic segment. For example, in the bending-back gesture, the speaker produced the stroke of the gesture just as he said, "bends it way back" (see Kita, 1993, for more subtle examples of how speech and gesture adjust to each other in timing, and Nobe, 2000). Typically, gesture precedes the word with which it is coexpressive, and the amount of time between the onset of the gesture and the onset of the word is systematic—the timing gap between word and gesture is larger for unfamiliar words than for familiar words (Morrel-Samuels & Krauss, 1992). The systematicity of the relation suggests that gesture and speech are part of a single production process. Indeed, gesture and speech are systematically related in time even when the speech production process goes awry. For example, gesture production is halted during bouts of stuttering (Mayberry & Jaques, 2000). Synchrony of this sort underscores once again that gesture and speech form a single integrated system.

Gesture and Speech Represent Information Differently

As mentioned earlier, speech conforms to a codified, recognizable system. Gesture does not. We are forced to package our thoughts using the words and structures that our language offers us, whereas gesture gives us a measure of flexibility. For example, it is difficult to adequately describe the coastline of the eastern seaboard of the United States using words alone (Huttenlocher, 1973, 1976). A gesture, unencumbered by the standards of form that language imposes, and able to take advantage of visual imagery, can convey the shape of the coastline far better than even a large number of words.

For the most part, gesture conveys information through imagery. A fist moves in a winding motion, conveying the action performed on the wind-up crank of an old car (Beattie & Shovelton, 1999). A loose palm traces an arc in the air, conveying the trajectory of a cat's flight on a rope into a wall (Ozyurek & Kita, 1999). A pointing finger moves back and forth between two rows of checkers, pairing the checkers and thus conveying the one-to-one correspondence between the checkers in the two rows (Church & Goldin-Meadow, 1986). In each case, the hand in motion makes use of visual imagery to convey meaning.

One feature of visual imagery is that it can present simultaneously information that must be presented sequentially in speech. For example, when commenting on a spider that he sees on the kitchen counter, a speaker says, "There's a spider running across the counter," while moving his hand, all five fingers wiggling, over the counter. The gesture presents, in a single motion, information about the spider (it has many legs, as indicated by all five fingers moving), the manner of motion (running, as indicated by the wiggling fingers), the path (across, as indicated by the path of the hand), and location (the counter, as indicated by the place where the gesture is produced).

In contrast, the scene must be broken up into parts when it is conveyed in speech. The effect is to present what had been a single instantaneous picture in the form of a string of segments: the spider, the running, the direction, the location. These segments are organized into a hierarchically structured string of words. Speech then has the effect of segmenting and linearizing meaning. Segmentation and linearization are essential characteristics of all linguistic systems (including sign languages), but not of gesture (Goldin-Meadow, McNeill, & Singleton, 1996).

Thus, gesture conveys meaning globally, relying on visual and mimetic imagery. Speech conveys meaning discretely, relying on codified words and grammatical devices.

Gesture Can Convey Information Not Found in Speech

Because gesture and speech use such different forms of representation, it is difficult for the two modalities to contribute identical information to a message. Indeed, even deictic pointing gestures are not completely redundant with speech. For example, when a child says the word *shoe* while pointing at the shoe, the word labels and thus classifies (but does not locate) the object. The point, in contrast, indicates where the object is but not what it is. Word and gesture do not convey identical information, but they work together to more richly specify the same object.

But word and gesture can, at times, convey information that overlaps very little, if at all. A point, for example, can indicate an object that is not referred to in speech—the child says "Daddy" while pointing at the shoe. Word and gesture together convey a simple proposition —"the shoe is Daddy's"—that neither modality conveys on its own.

As another example, consider a child participating in a Piagetian conservation task and asked whether the amount of water changed when it was poured from a tall, skinny container into a short, wide container. The child says that the amount of water has changed "cause that's down lower than that one," while first pointing at the relatively low water level in the short, wide container and then the higher water level in the tall, skinny container. Again, word and gesture do not convey identical information—speech tells us that the water level is low, gesture tells us how low—yet they work together to more richly convey the child's understanding.

In contrast, another child gives the same response in speech, "cause this one's lower than this one," but indicates the *widths* (not the heights) of the containers with her hands (two C-shaped hands held around the relatively wide diameter of the short, wide container, followed by a left C-hand held around the narrower diameter of the tall, skinny container). In this case, word and gesture together allow the child to convey a contrast of dimensions that neither modality conveys on its own (this one's lower but wide, and that one's higher but skinny).

We can posit a continuum based on the overlap of information conveyed in gesture and speech. At one end of the continuum, gesture elaborates on a topic that has already been introduced in speech. At the other end, gesture introduces new information that is not mentioned at all in speech. Although at times it is not clear where to draw a line to divide the continuum into two categories, the ends of the continuum are obvious and relatively easy to identify. In previous work (Church & Goldin-Meadow, 1986), we have called cases in which gesture and speech convey overlapping information *gesture–speech matches,* and cases in which gesture and speech convey nonoverlapping information *gesture–speech mismatches* (see also Goldin-Meadow, Alibali & Church, 1993).

The term *mismatch* adequately conveys the notion that gesture and speech convey different information. However, for many, mismatch also brings with it the notion of conflict, a notion that we do not intend. The pieces of information conveyed in gesture and in speech in a mismatch need not conflict and, in fact, they rarely do. There is almost always some framework within which the information conveyed in gesture can be fitted with the information conveyed in speech. For example, it may seem as though a conflict between the *height* information conveyed in the child's words ("lower") and the *width* information conveyed in her gestures. However, in the context of the water conservation problem, the two dimensions actually compensate for one another. Indeed, it is essential to understand this compensation—that the water may be lower than the original dish, but it is also wider—to master conservation of liquid quantity. Thus, the information conveyed in gesture in a mismatch is different from, but has the potential to be integrated with, the information conveyed in speech.

Gesture–speech mismatches are produced throughout the life span and in a wide variety of situations. Mismatches have been observed in toddlers going through a vocabulary spurt (Gershkoff-Stowe & Smith, 1997); preschoolers explaining a game (Evans & Rubin, 1979) or counting a set of objects (Alibali & DiRusso, 1999; Graham, 1999); elementary school children explaining Piagetian conservation problems (Church & Goldin-Meadow, 1986), mathematical equations (Perry, Church, & Goldin-Meadow, 1988), and seasonal change (Crowder & Newman, 1993); children and adults discussing moral dilemmas (Church et al., 1995); children and adults explaining how they solved Tower of Hanoi puzzles (Garber & Goldin-Meadow, 2002); adolescents explaining when rods of different materials and thicknesses will bend (Stone, Webb, & Mahootian, 1991); adults explaining how gears work (Perry & Elder, 1997; Schwartz & Black, 1996); adults describing pictures of landscapes, abstract art, buildings, people, machines, and so on (Morrel-Samuels & Krauss, 1992); adults describing problems involving constant change (Alibali, Bassok, Olseth, Syc, & Goldin-Meadow, 1999); and adults narrating cartoon stories (Beattie & Shovelton, 1999; McNeill, 1992; Rauscher, Krauss, & Chen, 1996).

Thus, we find gesture–speech mismatches in all sorts of speakers and situations. Sometimes the mismatching gesture is absolutely essential for the spoken sentence to make sense. For example, an adult narrating a cartoon story says, "so the hand is now trying to start the car," an odd formulation and one that is difficult to make sense of without the accompanying gesture—a hand moving in a winding motion, which lets the listener know that the car is an old one started with a crank (Beattie & Shovelton, 1999, p. 5). In other instances, speech *can* stand on its own, but it takes on a different sense when interpreted in the context of gesture. For example, Kendon (1985, p. 225) describes a husband sitting in the living room and talking with his wife about what the children had done that day. He says, "They made a cake, didn't they?"—a sentence that appears quite straightforward. However, while producing the word *cake,* the speaker gestured toward the garden, thereby indicating that the activity had taken place not in the kitchen but in the garden, and implying that the cake was of the mud variety. In both cases, gesture conveys information that cannot be found in, and is not even implied by, the accompanying speech.

The fact that gesture can, and often does, convey information that is distinct from the information conveyed in speech creates an opportunity for gesture to have its own unique impact on communication. This is the topic to which we turn in the next section.

ROLE OF GESTURE IN COMMUNICATION OVER THE LIFE SPAN

Do Speakers Intend Their Gestures to Communicate?

We first ask whether speakers intend to communicate information with their gestures. The easiest way to explore this question is to ask people to talk when they can and cannot see their listener. If we gesture in order to convey information to our listeners, we ought to gesture more when our listeners can see our hands than we they cannot see them.

A number of studies have manipulated the presence of a listener and observed the effect on gesture. In most studies, the speaker has a face-to-face conversation with a listener in one condition, and a conversation in which a barrier prevents the speaker and listener from seeing one another in the second condition. In some studies, the second condition is conducted over an intercom, and in some, the first condition is conducted over a videophone. In some studies, the camera is hidden so that the speakers have no sense that they are being watched. It does not really seem to matter—speakers gesture more when they can see their listener than when they cannot see them (Cohen & Harrison, 1973; Emmorey & Casey, 2001; Krauss, Dushay, Chen, & Rauscher, 1995; but see Rimé, 1982; Lickiss & Wellens, 1978). However, speakers do not increase their production of all gestures. For example, Bavelas, Chovil, Lawrie, and Wade (1992) found that speakers produced more interactive gestures (gestures that refer to the listener) when they could see their listener than when they could not, but not more topic gestures (gestures that refer to the topic of conversation). Similarly, Alibali, Heath, and Myers (2001) found that speakers produced more representational gestures (gestures that depict semantic context) when they could see their listener than when they could not, but not more beat gestures (simple, rhythmic gestures that do not convey semantic context).

Another way to explore whether speakers intentionally use their gestures to communicate is to vary some aspect of the listener, rather than merely varying the listener's presence or absence. Ozyurek (2000, 2002) asked speakers to retell a cartoon story to different numbers of listeners sitting in different locations. She found that speakers changed their gestures as a function of the positioning of their listeners, in particular, as a function of how the speaker's and listeners' gesture spaces intersected—their shared space. For example, when describing how Granny threw Sylvester the cat onto the street, speakers would change the direction of their gesture so that it moved out of the shared gesture space, wherever that space was. If the speaker shared the space with two listeners sitting at her right and left sides, that space was larger than it would be if the speaker shared the space with one listener sitting at one side—and the outward motion of the speaker's gesture varied accordingly. Perhaps not surprisingly, "out of" looked different depending on what was considered "in." What's important for our discussion here is that the speakers took their listeners into account when fashioning their gestures, suggesting that they were, at least in part, making those gestures for the listeners.

But do speakers really intend to produce gestures for their listeners? There is no doubt that speakers change their *talk* in response to listeners. Perhaps the changes in gesture come about as a by-product of these changes in speech. Speakers could alter the form and content of their talk, and those changes could "automatically" bring with them changes in gesture. To address this possibility, we need to examine not only changes that occur in gesture as a function of who the listener is, but also changes that occur in the accompanying speech. Alibali, Heath, and Myers (2001) examined the amount, fluency, and content of the speech in their face-to-face and screen conditions, and found no evidence to support this hypothesis—speakers used essentially the same number of words, made the same number of speech errors, and said the same things whether a listener was present or not. Thus, when speakers produced more gestures with visible than nonvisible listeners, it was not because they had changed their talk—it looks like they meant to change their gestures.

Up to this point, we have been stressing the fact that speakers gesture more when they address visible listeners than nonvisible listeners. There does appear to be a communicative aspect to gesturing. However, in each of these studies, speakers continued to gesture even when there was no listener there at all. Although statistically less likely, gesture was produced in *all* of the experimental conditions in which there was no possibility of a communicative motive. It looks like we gesture not only for others but also for ourselves (cf. Overton, 2006, who argues that all acts have an expressive-constitutive and an instrumental-communicative function).

Perhaps the most striking bit of evidence for this claim comes from congenitally blind individuals who have never seen speakers move their hands as they talk, and thus have no model for gesturing. Nonetheless, congenitally blind speakers gesture when they talk. They even gesture when speaking to a blind listener. Iverson and Goldin-Meadow (1998, 2001) asked 12 children and adolescents blind from birth to participate in a series of conservation tasks, and compared their speech and gesture on these tasks to age- and sex-matched sighted individuals. They found that all 12 blind speakers gestured as they spoke, despite the fact that they had never seen gesture or their listeners. The blind group gestured at the same rate as the sighted group, and conveyed the same information using the same range of gesture forms. In addition, Iverson and Goldin-Meadow (1998) asked four more children each blind from birth to participate in conservation tasks conducted by a blind experimenter. Here again, the blind speakers gestured and gestured at the same rate as the sighted-with-sighted dyads and the blind-with-sighted dyads. Speakers apparently do not gesture solely to convey information to a listener.

The issue of communicative intention still remains: Do we really intend to convey information to others with our gestures? In the end, the debate seems difficult, perhaps impossible, to resolve. On the one hand, we adjust our gestures to our listeners, and thus seem to be taking their needs into account. On the other hand, we gesture when no one is around, even when addressing blind listeners who cannot possibly profit from the information conveyed in our gestures. Even if it turns out that speakers do not tailor their gestures to the needs of their listeners, gesture may still play an important role in communication. It may not matter whether we intend to use our hands to convey information to our listeners. All that may matter is that our listeners are able to grasp whatever information lies in our hands. We explore whether listeners have this skill in the next section.

Can Listeners Glean Information from the Gestures They See?

There is clearly information to be gotten out of gesture. If individuals are trained to code hand shape and motion forms, and to attribute meanings to those forms, they are able to reliably describe the information that gesture conveys. But just because trained individuals can get meaning from gesture does not mean that untrained listeners can.

How can we tell if untrained listeners can understand gesture? At first blush, it might seem that the best way to approach this question would be to present gesture to listeners without speech and ask them what they think it means. Listeners can, in fact, glean a small amount of information from gesture when it is viewed without speech

(Feyereisen, van de Wiele, & Dubois, 1988; Krauss, Morrel-Samuels, & Colasante, 1991). However, unless our goal is to examine emblems (which are meant to be interpreted without speech), we are taking gesture out of its normal habitat in this type of manipulation—the gestures that accompany speech are not meant to be interpreted away from the framework provided by speech. As a result, studies of this type cannot tell us whether listeners glean information from the gestures they routinely see speakers produce.

There are a number of ways to figure out how much information listeners glean from gestures produced along with speech, some more convincing than others. We review the approaches that have been taken, beginning with a look at how listeners respond to speech when it is presented with and without gesture, and ending with what we think is the most convincing way to address this question (we look at gesture that conveys information not found in the speech it accompanies; in other words, we look at the gestural component of a gesture–speech mismatch and whether listeners can glean information from it).

There are hints that we pay attention to gesture from observations of how listeners behave in naturalistic conversations (see, for example, Kendon, 1994). Although naturalistic examples are suggestive, they cannot be definitive simply because we have no idea what a listener is actually understanding when he nods his head. The listener may *think* he's gotten the point of the sentence, but he may be completely mistaken. He may even be pretending to understand. We need to know exactly what listeners are taking from gesture to be sure that they have truly grasped its meaning. To accomplish this goal, we turn to experimental approaches.

Graham and Argyle (1975) conducted one of the very first studies designed to explore the effect of gesture on the listener. A speaker described a series of abstract line figures to listeners who could not see the figures and were asked to make drawings of the shapes described to them. Each speaker described half of the pictures using gesture freely, and half with his or her arms folded. A separate panel of judges analyzed the listeners' drawings for similarity to the original drawing and assigned each drawing an "accuracy" score—an assessment of how much information the listener took from the speaker's message. This measure can be compared for drawings done following messages with gesture versus messages without gesture.

The effect was large. Listeners created significantly more accurate drawings when presented with messages that were accompanied by gesture than when presented with messages that were gesture free. The effect was particularly large for line drawings that were difficult to describe in words. Allowing gesture to accompany speech improves the accuracy with which shapes can be communicated. The problem, however, is that the speakers could be changing their speech when they are not permitted to gesture (see Graham & Heywood, 1975), and listeners could be responding to the difference in speech (rather than to the presence of gesture) in the two conditions.

To get around this problem, we need to control speech. Thompson and Massaro (1986) did just that in a study exploring how pointing gestures affect listeners' perception of speech sounds. Listeners saw two objects, a ball and a doll, and heard synthesized speech sounds that corresponded either to /ba/ or /da/, or to sounds intermediate between these two syllables. The listener's job was to indicate whether the ball or the doll had been referred to in speech. Listeners either heard the sounds on their own, or they heard them in conjunction with a gesture (a person was seated behind the objects and pointed to one of the two objects). Sometimes the object that was pointed to was the same as the object referred to in speech (point at ball + /ba/) and sometimes it wasn't (point at doll + /ba/). The listeners' decision about which object had been referred to was strongly influenced by the pointing gesture: They were more likely to choose the ball when they saw a point at the *ball* while hearing /ba/ than when they saw a point at the *doll* while hearing /ba/. Moreover, the pointing gesture influenced the listeners' judgments to a greater extent when the speech information was ambiguous (i.e., when points were used in conjunction with the intermediate sounds between /ba/ and /da/).

However, it is more difficult to tell whether gesture is playing a communicative role when the gesture is iconic simply because the information conveyed in an iconic gesture often overlaps with the information conveyed in the speech it accompanies. When gesture and speech convey overlapping information, we can never really be sure that the listener has gotten *specific information* from gesture (e.g., Riseborough, 1981). Even if a listener responds more accurately to speech accompanied by gesture than to speech alone, it could be because gesture is heightening the listener's attention to the speech—gesture could be serving as an energizer or focuser, rather than as a supplier of information.

One way we can convince ourselves that the listener is gleaning specific information from gesture is to look at instances where that information is not conveyed *anywhere* in speech. Under these circumstances, the information must be coming from gesture. McNeill, Cassell, and McCullough (1994) created stimuli in which gesture conveyed different information from the information conveyed in speech. Several types of mismatches were included in the narrative, some that never occur in natural communication and some that are quite common. As an example of a match, the narrator wiggles the fingers of a downward-pointing V hand shape as he moves his hand forward while saying, "And he's running along ahead of it"—gesture and speech both convey running across. In the mismatch, a relatively uncommon one in natural discourse, the narrator produces precisely the same gesture while saying, "And he's climbing up the inside of it"—gesture again conveys running across, but speech conveys climbing up. Do listeners notice discrepancies of this sort, and if so, how do they resolve them?

Listeners did, indeed, notice the discrepancies and often resolved them by incorporating information conveyed in the gestures they saw into their own speech (McNeill et al., 1994). For example, the narrator on the videotape says, "He comes out the bottom of the pipe," while bouncing his hand up and down—a verbal statement that contains no mention of how the act was done (i.e., no verbal mention of manner), accompanied by a gesture that does convey manner. The listener resolves the mismatch by inventing a staircase. In her retelling, the listener turns the sentence into "and then goes down stairs across—back across into," while producing a manner-less gesture, a dropping straight down motion. Notice that the listener has not only picked up the information conveyed uniquely in gesture (the bouncing manner), but has incorporated it into her speech. The listener must have stored the bouncing manner in some form general enough to serve as the basis for her *linguistic* invention ("stairs").

Listeners can even glean information from gesture–speech mismatches that are spontaneously produced. In these studies, listeners are shown videotapes of children explaining their responses to conservation (Goldin-Meadow, Wein, & Chang, 1992) or math (Alibali, Flevares, & Goldin-Meadow, 1997; see also Goldin-Meadow & Sandhofer, 1999) tasks. In half of the explanations, children are producing gestures that convey the same information as their speech; in the other half, children are producing gestures that convey different information from their speech. If adults are responding only to the fact that the children are moving their hands, they should react to mismatches in the same way that they react to matches. However, if adults are responding to the *content* of the children's gestures, they ought to react differently to mismatches than to matches. In particular, because a mismatch contains two messages, one in speech and one in gesture, adults who are gleaning information from gesture might say more when they assess a child who produces a mismatch than when they assess a child who produces a match. And they did. In both studies, adults produced many more "additions"—that is, they mentioned information that could not be found anywhere in the speech of the child they were assessing—when evaluating children who produced mismatches than when evaluating children who produced matches. Moreover, more than half of the additions that the adults produced could be traced back to the gestures that the children produced in their mismatches.

One additional point deserves mention. Some of the adults in the study were very aware of the children's gestures and remarked on them in their assessments of the children's knowledge. Interestingly, however, these adults were no better at gleaning substantive information from the children's gestures than were the adults who failed to mention gesture. Thus, being explicitly aware of gesture (at least enough to talk about it) is not a prerequisite for decoding gesture.

The gesture-reading situation in the studies we have just reviewed seems a bit removed from the real world. It would be more convincing to examine adults interacting with real-live children producing whatever gestures they please. Goldin-Meadow and Singer (2003; see also Goldin-Meadow, Kim, & Singer, 1999) asked teachers to instruct a series of children individually in mathematical equivalence, and then looked at how the *teachers* responded to the children's gestures, as well as how the *children* responded to the teachers' gestures. They found that both teachers and children reiterated the problem-solving strategies that their partner produced in the gesture half of a gesture–speech mismatch. Moreover, both teachers and children often recast the strategy that had appeared uniquely in gesture into their own words. In other words, they were able to read their partner's gestures, even in a relatively naturalistic setting.

ROLE OF GESTURE IN COGNITION OVER THE LIFE SPAN

We have seen that gesture can play an influential role in communication. It is part of the give-and-take between speakers and listeners, often conveying information that is not found in speech, but that listeners are nonetheless able to interpret. But gesture does more than contribute to communication. It plays an equally important role in cognition.

Some of the most convincing evidence that gesture plays a role in cognition comes from the fact that speakers' gestures, in particular, their gesture–speech mismatches, are a reliable index that they are at a transitional point and on the verge of change.

Gesture Predicts Change

We begin by noting that a person who produces gesture–speech mismatches on one task will not necessarily produce them on another. For example, children who produce many mismatches when explaining how they solved a mathematical equivalence task may produce none at all when explaining how they solved an (easier) conservation task (Perry et al., 1988). Even within the same domain, a speaker may produce many mismatches on a hard task and few on an easy task. For example, 2-year-olds produce more mismatches when counting a relatively large set of objects (four or six objects) than when counting a small set (two objects). For 3-year-olds, who know more about counting, the pattern is the same but the line between easy and hard falls at a different point—they produce mismatches only when counting six object sets and not when counting two or four object sets (Graham, 1999).

Rather than reflecting who a person is, gesture–speech mismatch reflects how ready a person is to learn about a particular task. A speaker who produces gesture–speech mismatches on a task is likely to be in a state of transition with respect to that task, ready to profit from whatever input manages to come her way. The evidence for this claim comes from experimental training studies, as well as studies of more naturalistic learning situations.

Church and Goldin-Meadow (1986) gave 5- to 8-year-old children a pretest of six conservation problems to assess their understanding of conservation and to determine whether the children produced a relatively large number of gesture–speech mismatches (mismatchers) or a small number (matchers). They then gave all of the children instruction in the task: half were given explicit instruction in conservation, and half were given experience in manipulating the task objects but no training or feedback. After the instruction, children were given the six conservation problems again and their improvement from pretest to post-test was assessed. Church and Goldin-Meadow (1986) found, not surprisingly, that children given explicit instruction made more progress than children given only the opportunity to manipulate the objects. However, the important point is that, no matter what type of instruction the children received, mismatchers made significantly more progress than matchers. Importantly, the matchers and the mismatchers did *not* differ on the pretest. Before instruction, the *only* way to tell the groups apart was by the number of gesture–speech mismatches each produced.

Gesture–speech mismatch in a child's explanations of conservation is thus a sign that the child is ready to learn about conservation. But is gesture–speech mismatch a general index of readiness-to-learn, or is it specific to the conservation task or to 5- to 8-year-olds? To address this question, Perry, Church and Goldin-Meadow (1988) gave older children (9- to 10-year-olds) instruction in mathematical equivalence, instantiated in problems of the following type: $4 + 5 + 3 = \_\_ + 3$. When asked to explain how they arrived at the number they put in the blank, children typically gesture while talking and often produce gesture–speech matches. For example, for the problem $6 + 3 + 4 = \_\_ + 4$, a child puts 13 in the blank and says "6 plus 3 is 9, 9 plus 4 equals 13," while pointing at the 6, the 3, the 4 on the left side of the equation, and the 13 in the blank. The child has produced an add-to-equal-sign strategy in both speech and gesture, a gesture–speech match. However, children also produce gesture–speech mismatches. Another child says he added the 6, the 3, and the 4 (an add-to-equal-sign strategy), while at the same time pointing at all four numbers in the problem (an add-all numbers strategy). This child has conveyed one strategy in speech and another in gesture, a gesture–speech mismatch.

Perry et al. (1988) gave children in the fourth and fifth grades a pretest of six addition problems to assess their understanding of mathematical equivalence and to determine whether the children were mismatchers or matchers. They then gave the children instruction in the principle underlying the addition problems—the children were told that the goal of the problem was to make both sides of the equation equal. After the instruction session, the children were again given six addition problems, and a series of novel addition and multiplication problems that tested their ability to generalize what they had learned. Here again, significantly more mismatchers were successful after instruction than matchers, on both the post-test and a generalization test. Similar results have been found for other tasks and other ages (balance scale problems: Pine, Lufkin, & Messer, 2004; gears task: Perry & Elder, 1997).

One advantage of a training study (as opposed to waiting for learners to change on their own) is time; the changes we want to observe occur over a short rather than a long period (hours as opposed to weeks). Another advantage is that we can control the instruction that the learner gets, which means that if we find differential effects after instruction (as we do), those effects cannot be attributed to differences in input, but rather to differences in the learners themselves (their status as a matcher or mismatcher). However, there are also benefits to looking at learning as it occurs in more naturalistic circumstances, not the least of which is that it would be nice to know whether gesture–speech mismatch has anything to do with learning in the real world. A study of math teachers suggests that it does.

Goldin-Meadow and Singer (2003) asked math teachers to instruct 9- and 10-year-old children individually in mathematical equivalence. The teacher watched while an experimenter gave the child a pretest consisting of six mathematical equivalence problems. Children who solved even one problem correctly were eliminated from the study. The teacher then instructed the child using any techniques that he or she thought appropriate. After the tutorial, the child was given a post-test comparable with the pretest. The children could be divided into three groups on the basis of the explanations they produced during the pretest and training: those who never produced mismatches at any point during the testing or instruction, those who produced mismatches only during instruction, and those who produced mismatches during the pretest and typically during instruction as well.

The interesting result is that the children's post-test scores reflected these groupings: Children who produced mismatches on the pretest solved more problems correctly on the post-test than children who produced mismatches only during instruction, who, in turn, solved more problems correctly than children who never produced mismatches. Thus, the children who produced mismatches were far more likely to profit from the teacher's instruction than the children who did not. Of course, the teachers may have altered their instruction as a function of the children's gestures, treating matchers differently from mismatchers. If so, it may have been the child's gestures that let the teacher know the child was ready for a different kind of input, thus playing a pivotal role in the learning process. We return to this very real possibility in a later section.

Why does gesture predict learning? Expressing information in gesture and not in speech is a type of variability, and variability seems to be good for learning. Siegler (1994) describes three types of within-child variability common to children. First, a child may solve the same type of problem in different ways. For example, a child uses the "add-to-equal-sign" strategy to solve the problem 4 + 5 + 3 = __ + 3, but the "add-all-numbers" strategy to solve 7 + 5 + 4 = __ + 4. The second problem has the same structure as the first and differs from it only in its particular numbers. The child thus has more than one way of solving problems of this type at her disposal. Second, a child may solve precisely the same problem in different ways. If the child were given the 4 + 5 + 3 = __ + 3 problem twice, such a child might solve it first using an "add-to-equal-sign" strategy and then an "add-all-numbers" strategy (cf. Siegler & McGilly, 1989; Siegler & Shrager, 1984; Wilkinson, 1982). Finally, a child may use two different strategies when solving a single problem. The prototypical example of this type of within-child variability is mismatch—the child solves the problem using an "add-to-equal-sign" strategy that she expresses in speech while at the same time expressing an "add-all-numbers" strategy in gesture. By definition, a mismatch is an utterance in which gesture conveys different information from speech. It is a response that, in a sense, contains two responses.

Why should we care about variability? There are both theoretical and empirical reasons to believe that variability is important to change (see Nesselroade & Molenaar, Chapter 2 of this volume for an extended discussion of the significance of variability to change). Theories that posit internal conflict as a mechanism of change (e.g., Piaget's equilibration theory, 1975/1985) assume that the impetus for transition comes from having more than one rule for solving a problem, and noting discrepancies among those rules. Detecting discrepancy leads to disequilibrium, which then acts as an impetus for change (see, for example, Langer, 1969; Overton & Ennis, 2006; Snyder & Feldman, 1977; Strauss, 1972; Strauss & Rimalt, 1974, within the Piagetian tradition; and Turiel, 1974, Chapter 16 of this volume, within the domain of moral development). Even traditions that are distinctly non-Piagetian have proposed that multiple solutions to a problem may be characteristic of a changing state. Take, for example, Keil (1984), who lists resolution of internal inconsistencies as a possible mechanism of change, and Fischer (1980), who argues that change comes about when two or more skills with an old structure are transformed into skills with a new structure. From an information-processing perspective, Klahr (1984) lists conflict-resolution rules—rules that apply when two productions are eligible to be activated on a single problem—as an important mechanism of change in self-modifying systems. From a Vygotskian perspective, Griffin and Cole (1985) argue that the zone of proximal development embodies multiple levels, both next steps and previous steps. Finally, a number of more contemporary descriptions of cognitive change argue that new understanding emerges when two different levels of knowledge are integrated (e.g., Bidell & Fischer, 1992; Smith, 2005; Smith & Breazeal, 2007; Thelen & Smith, 1994; Zelazo, Frye, & Rapus, 1996). The common thread running through all these theories is the notion that more than one approach is activated or considered in solving a problem, and that the simultaneous activation of a variety of approaches is good for learning.

Empirical work supports the link between variability and change. Across a range of tasks, individuals display variability just before making a cognitive change (Thelen & Smith, 1994; Turiel, 1969, 1974; Walker & Taylor, 1991). Take, for example, children in the process of discovering a new way to solve a simple addition problem. The children exhibit variable behavior on trials immediately before the discovery and when the discovery itself is made (Siegler & Jenkins, 1989). As another example, adults who profited from instruction in how gears work had a variety of approaches to the problem in their repertoires before instruction—many more than adults who did not profit from the instruction or who understood how gears work from the start (Perry & Elder, 1997). And, of course, there is our own finding that children who produce many mismatches on a task (two responses on a single problem) are more likely to profit from instruction on that task than children who produce few (Church & Goldin-Meadow, 1986; Goldin-Meadow & Singer, 2003; Perry et al., 1988). Variability is associated with learning.

Gesture–speech mismatch is clearly one type of variability that is associated with change. But is it special in any way? Mismatch does, in fact, have some unique features. First, the different approaches are activated on a single problem in a mismatch, which could encourage comparison across the approaches. Second, the different approaches are expressed in different modalities, one in speech and the other in gesture. Perhaps having a variety of representational formats is itself an important catalyst leading to change (see Church, 1999).

We have seen that gesture is associated with learning. It can index moments of cognitive instability and reflect thoughts not found in speech. Gesture is, therefore, an ideal tool for researchers interested in identifying who is on the verge of learning and figuring out what those learners know that they cannot say. But might gesture do more than just reflect learning? The following sections explore whether gesture is involved in the learning process itself.

Gesture Brings About Change by Affecting the Learning Environment

We have seen that an undercurrent of conversation takes place in gesture alongside the acknowledged conversation in speech. Children who are on the verge of change gesture differently from children who are not. When a student's gestures convey information that is different from the information found in speech, those gestures can inform the teacher of thoughts that the student has but cannot (or at least does not) express in speech. Gesture may be one of the best ways that teachers have of discovering thoughts that are on the edge of a student's competence—what Vygotsky (1978) called the child's "zone of proximal development" (the set of skills a child is actively engaged in developing).

In fact, teachers do notice, and rely on, the gestures children produce in a classroom situation. For example, students in a science lesson were asked by the teacher whether the shadows cast by a streetlight (actually a light bulb hung from a ladder) on a line of 20-cm sticks would get longer, shorter, or stay the same as the sticks got farther away from the ladder. In response, one child said, "I think that the longer one's gonna have a longer shadow and the shorter one's shadow gonna be…," while pointing to sticks *farthest* from the ladder. The teacher restated his ideas for the classroom as follows: "So the ones up here closer to the light bulb are gonna have shorter ones and the ones further away are gonna have longer ones" (Crowder, 1996, p. 196). The teacher focused on the objects that the student had referred to in gesture rather than speech (see also Roth & Welzel, 2001). It is not clear, in this instance, whether the teacher knew he was making inferences about his student's thoughts on the basis of the student's gestures. However, at times, teachers can be quite aware of their students' gestures and even ask the students directly to make their gestures more explicit (Crowder & Newman, 1993).

But teachers do not always notice the comments that their students make in gesture. When students produce gesture-rich but lexically limited expressions, teachers at times overlook those gestured contributions even if they are key to the discussion (Crowder & Newman, 1993). Not being ratified by the teacher, the comments that appear in gesture and not speech—which often are at the forefront of the student's knowledge—may then be lost to the group and to subsequent discussion.

Responding in a tailored way to a child's individual needs is difficult in a classroom situation. But teachers might be able to use children's gestures to tailor instruction to them in a one-on-one tutorial. As described earlier, Goldin-Meadow and Singer (2003) asked teachers to individually instruct children in mathematical equivalence. Before instructing each child, the teacher observed the child solving a series of math problems and explaining her solutions. Would teachers adjust their instruction as a function of the gestures that the children spontaneously produced during the lesson? As it turns out, they did. Teachers taught children who produced gesture–speech mismatches more and different kinds of strategies for solving the problems than they taught children who did not produce mismatches. In addition, the teachers produced more gesture–speech mismatches of their own when teaching children who produced gesture–speech mismatches than they produced when teaching children who did not produce mismatches. Thus, the teachers gave the mismatching children instruction that was more varied than the instruction they gave the matching children.

Did the instruction that the teachers spontaneously offered their pupils facilitate learning? To find out, Singer and Goldin-Meadow (2005) designed lessons based on the teachers' spontaneous instructional strategies and used those lessons to teach groups of fourth graders mathematical equivalence. The instruction varied along two dimensions: (1) Some lessons contained only one spoken strategy, and others contained two; (2) some lessons contained gestures conveying a different strategy from speech, some contained gestures conveying the same strategy as speech, and some contained no gestures at all. They found that giving children instruction containing two instructional strategies was effective, but only when the two strategies were conveyed in different modalities, one in speech and another in gesture, or in other words, when the two strategies were produced in a gesture–speech mismatch.

The following picture is emerging from these findings: Children produce gestures that reveal the edges of their knowledge. Teachers read these gestures and adjust their instruction accordingly. Children then profit from this instruction that has been tailored to their needs. Children are able to shape their own learning environments just by moving their hands.

Although adults are able to glean information from children's gestures, they do not do it all of the time. Can we get teachers to improve their rates of gesture reading, which, in turn, might then help them get as much as they can out of their students' hands and mouths? To address this question, Kelly, Singer, Hicks, and Goldin-Meadow (2002) gave adults instruction in how to read gesture. They did a number of studies teaching adults to read the gestures that children produce on either conservation or mathematical equivalence tasks, and varying the instructions they gave the adults from giving a hint ("Pay close attention not only to what the children on the videotape say with their words, but also to what they express with their hands."), to giving general instruction in the parameters that experts use when describing gesture (hand shape, motion, placement), to giving specific instruction in the kinds of gestures children produce on that particular task. The adults were given a pretest, then the instructions, and finally a post-test to determine improvement.

The adults improved with instruction, even with just a hint; they picked up 30% more explanations that the child had expressed uniquely in gesture after getting a hint to attend to gesture than before, and 50% more after getting specific instruction in the gestures on the task than before. In fact, after the adults were given specific training, they were able to accurately decode the children's gestures 90% of the time on the conservation task and 60% on the math task (improvement was the same on the two tasks—before instruction, the adults were at a 40% level on conservation, but at a 10% level on math). Moreover, on both tasks, the adults were able to generalize the instruction they received to new gestures they had not seen during training. Importantly, improvement in reading gesture did not affect the adults' abilities to glean information from the children's speech on the conservation task—they identified the child's spoken explanations perfectly before and after instruction. There was, however, a slight decrement in the number of spoken explanations the adults reported after instruction on the math task (as in naturalistic situations, this decrement was offset by an increase in the number of gestured explanations the adults reported after instruction).

The challenge for us in future studies is to figure out ways to encourage teachers to glean information from their students' gestures, whereas at the same time not losing their students' words. The technique that seems fruitful is to instruct teachers to look for a framework that can unite the information the student conveys in both gesture and speech. Having such a framework in mind should make it easier for the teacher to process the information coming in from the two modalities. The added benefit is that the teacher can also make the framework explicit to the student—and the framework may be just what the student needs at this particular moment. The student already has the pieces but lacks the whole that could unify those pieces. If the student's gesture and speech are any indication, she may be particularly ready to accept such a framework.

Gesture Brings about Change by Affecting the Learner

This section considers whether gesture plays a role in the learning process more directly by influencing the learners themselves. Gesture externalizes ideas differently from speech and, therefore, may draw on different resources. Using both modalities to convey ideas may therefore allow different ideas to enter the system, or it may allow ideas to enter the system earlier and with less effort than if the ideas had been encoded in speech alone. If so, the act of gesturing may itself change thought.

Gesturing Lightens the Learner's Cognitive Load

If the act of gesturing is itself beneficial, we might expect that gesturing will increase as problems get harder. And it does. Gesturing increases when the speaker hears his own voice continuously echoing back to him (under conditions of delayed auditory feedback; McNeill, 1992); when the speaker has suffered a stroke, trauma, or tumor and has greatly impaired language abilities (Feyereisen, 1983); when the number of problems in a task increases (Graham, 1999; Saxe & Kaplan, 1981); when the speaker can choose among options (Melinger & Kita, 2007); when the speaker is describing a scene from memory (De Ruiter, 1998; Wesp, Hesse, Keutmann, & Wheaton, 2001); and when the speaker is reasoning rather than merely describing (Alibali, Kita, & Young, 2000). These observations provide evidence that gesturing is associated with thinking hard. But they do not yet convince us that gesturing contributes to making the task easier. To make that argument, we need to manipulate gesture—that is, take it away and see if doing so affects the amount of effort the speaker expends. If gesturing merely reflects effort expended and does not contribute in any way to making the task easier, we would expect no change in effort when speakers are prevented from gesturing (or, for that matter, when they are encouraged to gesture). If, however, gesturing actually makes the task easier, we would expect that speakers will increase the amount of effort they expend on a task when prevented from gesturing on the task (to make up for the lost benefits of gesture).

How can we measure the amount of effort an individual expends on a task? One technique often used by cognitive psychologists is to give individuals a second task to perform at the same time as they are performing the original task. If the first task is very costly (from a cognitive effort point of view), they will perform less well on the second task than they would have if the first task was less effortful (Baddeley, 1986). In other words, we can use performance on the second task to gauge how much effort an individual is expending on the simultaneously performed first task.

Goldin-Meadow, Nusbaum, Kelly, and Wagner (2001) explored how gesturing on one task (explaining a math problem) affected performance on a second task (remembering a list of words or letters) performed at the same time. If gesturing reduces cognitive load, gesturing while explaining the math problems should free up resources available for remembering. Memory should then be *better* when speakers gesture than when they do not gesture. If, however, gesturing increases cognitive load, gesturing while explaining the math problems should take away from the resources available for remembering. Memory should then be *worse* when speakers gesture than when they do not gesture. Finally, if gesturing merely reflects cognitive load but has no role in causing it, gesturing while explaining the math problems should have no effect on the resources available for remembering. Memory should then be the *same* when speakers gesture and when they do not gesture. Goldin-Meadow and colleagues (2001) individually tested children on addition problems of the form, $4 + 5 + 3 = \_\_ + 3$, and adults on factoring problems of the form, $x^2 - 3x - 10 = (\ )(\ )$. Children and adults were asked to solve a math problem at the blackboard. After doing so, they were given a list of items to remember (words for children, letters for adults) and were then asked to explain how they arrived at their solutions to the math problem. After completing the explanation, children and adults were asked to recall the list. The crucial part of the design is that the children and adults had to keep the to-be-remembered list in mind while explaining how they solved the math problem—the two tasks were performed simultaneously. The memory task could then serve as a gauge of how much effort each child and adult expended on the explanation task (Logan, 1979; Shiffrin & Schneider, 1984).

Children and adults gave explanations under two conditions: (1) gesture permitted, in which their hands were unconstrained; and (2) gesture not permitted, in which they were instructed to keep their hands still on the tabletop. Both children and adults remembered a significantly larger proportion of items when gesturing than when not gesturing, particularly on the long lists that taxed their memories. Thus, gesturing does not merely reflect cognitive load but appears to have an impact on the load itself. Moreover, that impact is beneficial—gesturing reduces rather than increases cognitive load.

There is, however, an alternative explanation: being forced not to gesture could itself hurt memory. If so, the effect might be not because of the beneficial effects of gesture, but the deleterious effects of the constraining instructions. Asking speakers not to gesture is, in effect, asking them to do yet another task, which could add to their cognitive load. To deal with this concern, Goldin-Meadow and colleagues (2001) reanalyzed the data focusing on a subset of the children and adults who spontaneously (and presumably, unconsciously) gestured on only some of the problems where gesturing was permitted. In other words, there were problems on which these individuals could have gestured but chose not to, allowing the researchers to compare the effects on memory of removing gesture by experimental design versus by the individual's spontaneous inclination. They reanalyzed the data from these children and adults, separating memory when they did not gesture *by choice* from memory when they did not gesture *by instruction.* Both children and adults remembered more when gesturing than when not gesturing either by choice or by instruction, suggesting that the act of gesturing really does lighten the burden on the speaker's working memory.

What might gesture be doing to reduce cognitive effort? There are a number of possibilities, all of which might be correct. First, gesture could lighten cognitive load by raising the overall activation level of the system so that words reach a firing level more quickly (Butterworth & Hadar, 1989). Under this view, any movement would do to raise activation, and the beneficial effects of gesture would have nothing to do with its ability to convey meaning. We know that this extreme view is not correct—the type of gesture speakers produce (in particular, whether it matches or mismatches the speech it accompanies) affects how much the speakers can recall on the secondary memory task (Wagner, Nusbaum & Goldin-Meadow, 2004). Nevertheless, it is possible that part of the reason gesture is effective in lightening load is because it engages the motor system.

Second, gesture might help speakers retrieve just the right word in their explanations (which would, in turn, save them cognitive effort so that they could perform better on the memory task). Gesture, particularly iconic gestures, might assist word finding by exploiting another route to the phonological lexicon, a route mediated by visual coding (Butterworth & Hadar, 1989). To test the role of gesture in lexical access, Rauscher, Krauss, and Chen (1996) prevented speakers from gesturing, whereas at the same time making lexical access more difficult (they asked speakers to try to use as many obscure words as possible, or to avoid using words that contain a specific letter). They found that preventing speakers from gesturing had the same effects as increasing the difficulty of lexical access by the other means. However, several studies designed to test the role of gesture in lexical access have found negative results. Beattie and Coughlan (1998) asked speakers to tell the same story on six consecutive trials. One would imagine that, at some point in the retellings, all of the words that the speaker might have had difficulty accessing in the first telling would have been accessed. The need for gesture (assuming that its function is to access words) ought to then decline. But gesture did not decline over the six retellings. It stayed constant throughout (see also Alibali, Kita & Young, 2000). Rather than manipulate the need for lexical access and observe the effects on gesture, Beattie and Coughlan (1999) manipulated gesture and observed the effects on lexical access. They gave speakers definitions of rare words and asked them to come up with the word that matched the definition. All of the words were rated high in imageability, and thus ought to have been easy to gesture. Half of the speakers were free to gesture and the other half was instructed to fold their arms. Speakers who were free to gesture actually reached the target word *less* often than those who had their arms folded (see Pine, Bird, & Kirk, 2007, for similar findings in children). Thus, although gesturing may reflect the fact that a speaker is in the throes of searching for a word (or has completed such a search, cf. Christenfeld, Schachter, & Bilous, 1991), it does not necessarily help the speaker find that word. Moreover, even when there seems to be little need to access a lexical item, speakers continue to gesture. Gesture could, of course, increase a speaker's access to a temporarily inaccessible lexical item on some occasions (cf. Pine et al., 2007). However, this function does not appear to be sufficiently widespread to account for gesture's beneficial effects on cognitive load.

A third possibility is that gesturing makes it easier to link a speaker's words to the world (cf. Glenberg & Robertson, 1999). Alibali and DiRusso (1999) asked preschool children to count objects. Sometimes the children were allowed to gesture while they counted and sometimes they weren't. The children counted more accurately when they gestured than when they did not gesture, suggesting that hooking word to world is easier for speakers when they can use their hands. Indeed, the children rarely made "coordination" errors (errors in coordinating the set of number words with the action of tagging each item) when they were allowed to gesture but made errors of this sort when they were prevented from gesturing. Alibali and DiRusso also included a third condition—they asked children to count aloud while a puppet gestured for them. Here, too, the children counted more accurately than when there was no gesture at all. However, unlike the self-gesturing trials, the errors that the children made on the puppet-gesturing trials tended to be coordination errors. Gesture helps speakers link words to the world, but apparently only when the speakers themselves produce those gestures. Note that the gestures in this study are what we might call *grounded* gestures—they refer concretely to objects in the world. Indeed, that is why these gestures serve the indexing function so well. The gestures in the math cognitive load studies were, for the most part, also grounded gestures (points at numbers strung together in different ways to convey problem-solving strategies). However, Ping and Goldin-Meadow (2008) recently conducted a cognitive load study using a task that tends to elicit nongrounded gestures (the conservation task). In addition, they asked half of the speakers to give their explanations with no objects around at all. They found that here again speakers remembered more when they gestured than when they did not, regardless of whether the objects were present, suggesting that indexing cannot be the sole explanation for the ability of gesture to reduce cognitive load.

Finally, gesturing could help speakers organize information, particularly spatial information, for the act of speaking and in this way ease the speaker's cognitive burden. Kita (2000) has argued that gesture helps speakers "package" spatial information into units appropriate for verbalization. If this hypothesis is correct, speakers should find it easier to convey spatial information when they gesture than when they do not. Alibali, Kita, Bigelow, Wolfman, and Klein (2001) asked children to explain their answers to a series of conservation tasks under two conditions: when they could move their hands freely, and when their hands were placed in a muff and therefore restrained. As expected, under the view that gesture helps speakers organize spatial information, children produced more perceptual-based explanations when they were allowed to move their hands freely than when they were not. Of course, the children could have changed the content of their explanations for the listener, that is, they could have adjusted their response to make up for the fact that the listener was or was not seeing gesture (as opposed to making the adjustment to benefit themselves). However, in a second study, Alibali and colleagues (2001) had a different set of children participate in the same task, with the exception that a curtain blocked the listener's view of the child's gestures. The results were unchanged—children produced more perceptual-based explanations when they were allowed to gesture than when they were not (see also Rime, Schiaratura, Hupet, & Ghysselinckx, 1984, for comparable results with adults). Although not conclusive, these studies suggest that gesture might play a role in helping speakers (as opposed to, or in addition to, listeners) organize spatial information into speech. This mechanism could well account for the beneficial effects that gesture has on a speaker's cognitive load in the math tasks, which do call on spatial skills. The open question is whether gesturing will also lighten cognitive load when the task is a nonspatial one (a moral reasoning task, for example).

More than one, or even all, of these hypotheses might explain how gesture lightens a speaker's cognitive load. Moreover, a theme underlies all of them: Gesture and speech form an integrated and, indeed, synergistic system in which effort expended in one modality can (at times, but probably not always) lighten the load on the system as a whole.

Gesturing Brings New Ideas into the Learner's Repertoire

We have seen that gesturing can aid thinking by reducing cognitive effort. Gesturing saves effort on a task. That effort can then be used on some other task, one that would have been performed less well had the speaker not gestured on the first task. Gesturing thus allows speakers to do more with what they have and, in this way, can lead to cognitive change. But gesturing may contribute to cognitive change in other ways as well. Gesture offers a route, and a unique one, through which new information can be brought into the system. Because the representational formats underlying gesture are mimetic and analog rather than discrete, gesture permits speakers to represent ideas that lend themselves to these formats (e.g., shapes, sizes, spatial relationships)—ideas that, for whatever reason, may not be easily encoded in speech. Indeed, gesture may serve as a medium in which learners are able to experiment with new ideas. For example, a child learning about conservation of number may recognize, at some level, that pairing the checkers in one row with the checkers in another row can tell him whether the two rows have the same number of checkers. The child may not yet be able to express the notion of one-to-one correspondence in words, but by tracing a zigzag path between the checkers in the two rows, she can express the notion in gesture. Once an idea is expressed in the manual modality, it may be able to serve as a catalyst for change. In other words, gesture sneaks ideas in through the back door, and once in, those ideas take up residence and flourish.

Experimental evidence for this hypothesis comes from a series of studies in which children were told to gesture while explaining their solutions to a math problem. These children produced more new—and correct—ideas in their gestures than children told not to gesture, and more than children given no instructions about their hands. Interestingly, at the same time that the children were producing these correct ideas in gesture, they continued to solve the problems incorrectly and articulated incorrect problem-solving strategies in their speech. However, when given instruction in how to solve the problems, children who were told to gesture were more likely to profit from the instruction than children who were told not to gesture (Broaders, Cook, Mitchell, & Goldin-Meadow, 2007). Gesturing thus brings out implicit ideas, which, in turn, lead to learning.

Even more striking, we can introduce new ideas into children's cognitive repertoires by telling them how to move their hands. For example, if we make children sweep their left hands under the left side of the mathematical equation 3 + 6 + 4 = __ + 4 and their right hands under the right side of the equation during instruction, they are more likely to learn how to correctly solve problems of this type than if they are told to say, "The way to solve the problem is to make one side of the problem equal to the other side" during instruction (Cook, Mitchell, & Goldin-Meadow, 2008). Telling children how to move their hands thus seems to introduce new ideas into their repertoires.

But just *how* does gesturing promote new ideas? Learners may extract meaning from the hand movements they produce. If this is the case, then learners should be sensitive to the particular movements they produce and learn accordingly. Alternatively, all that may matter is that learners move their hands. If so, they should learn regardless of the particular movements they produce. In fact, children who were told to produce movements instantiating a *correct* rendition of the grouping strategy during instruction (e.g., a V-hand placed under the 3 and 6 in the 3 + 6 + 4 = __ + 4 problem, followed by a point at the blank) solved more problems correctly after instruction than children told to produce movements instantiating a *partially correct* strategy (e.g., a V-hand placed under the 6 and 4, followed by a point at the blank; the gesture highlighted grouping two numbers but focused on the wrong two numbers), who, in turn, solved more problems correctly than children told not to gesture at all (Goldin-Meadow, Cook, & Mitchell, 2009). Importantly, this effect was mediated by whether children added the grouping strategy to their postinstruction spoken repertoires. Because the grouping strategy was never expressed in speech during instruction by either child or teacher, nor was it expressed in gesture by the teacher, the information that children incorporated into their postinstruction speech must have come from their own gestures.

Although the findings suggest that the children extracted information relevant to solving the problem from their hand movements, an alternative possibility is that the children's hand movements merely helped them focus their attention on the particular numbers that needed to be manipulated. Note, however, that the gestures children produced in the *partially correct* condition focused their attention on the wrong numbers. Nevertheless, children in this condition improved on the post-test, and did so more than children who did not gesture, making it unlikely that the sole function of gesture was to regulate attention. Rather, the gestures that the children produced appeared to help them learn the grouping operation, as evidenced by the fact that they added grouping to their spoken repertoires after the lesson. We may be able to lay foundations for new knowledge simply by telling learners how to move their hands. If this view is correct, even inadvertent movements of the hand have the potential to influence thinking, as has been suggested for adults solving mental rotation problems (Chu & Kita, 2008).

Thus, gesture does not just reflect the incipient ideas that a learner has; it can play a role in helping the learner formulate and, therefore, develop these new ideas. In other words, the course of cognitive change is different by virtue of the fact that the learner has gestured.

GESTURING EARLY IN DEVELOPMENT

We have seen that gesture plays a role in both communication and cognition in proficient language users. We next ask whether gesture plays the same kind of role at the earliest stages of development, during the period before language is mastered.

Role of Gesture in Communication in the Early Stages of Development

School-aged children seem to look just like adults in terms of their abilities to get meaning from gesture. Kelly and Church (1997, 1998) asked 7- and 8-year-old children to watch the videotapes of other children participating in conservation tasks. In half of the examples, the children on the videotape produced gesture–speech mismatches; in the other half, they produced gesture–speech matches. The children in the study watched the videotape twice. On one pass through, they simply described to the experimenter how they thought the child in the videotape explained his or her answer. On the other pass through, they filled out a checklist after watching each child on the videotape. No matter which technique the children used, they were able to get substantive information from other children's gestures. They produced more information when responding to mismatches, and much of the additional information could be traced back to the gestures on the videotape. They checked off explanations on the checklist that had appeared only in the gestures on the videotape. Like adults, they are able to glean specific meaning from gestures that are produced together with speech yet convey different meaning from speech.

The ability to interpret the gestures that accompany speech is not limited to school-aged children and adults—very young children can do it too. In fact, very early on, gesture-plus-word combinations seem to offer an easier route to the speaker's message than word-plus-word combinations. Young children respond to others' pointing gestures by directing their attention to the object indicated by the point, and do so months before they produce their own pointing gestures to orient another's attention toward an object (Allen & Shatz, 1983; Lempers, Flavell, & Flavell, 1976; Leung & Rheingold, 1981; Macnamara, 1977; Murphy & Messer, 1977).

But do young children integrate the information they get from the pointing gesture with the message they are getting from speech? Morford and Goldin-Meadow (1992) gave children, all of whom were in the one-word stage, "sentences" composed of a word and a gesture. For example, the experimenter said "push" while pointing at a ball, or "clock" while producing a give gesture (flat hand, palm facing up, held at chest level). If the children can integrate information across gesture and speech, they ought to respond to the first sentence by pushing the ball and to the second by giving the clock. If not, they might throw the ball or push some other object in response to the first sentence, and shake the clock or give a different object in response to the second sentence. The children did just as we might expect. They responded by pushing the ball and giving the clock—that is, their responses indicated that they were indeed able to integrate information across gesture and speech. Moreover, they responded more accurately to the "push" + point at ball sentence than to the same information presented entirely in speech—"push ball." For these one-word speakers, gesture + word combinations were *easier* to interpret than word + word combinations conveying the same information.

One more point deserves mention. The gesture + word combinations were more than the sum of their parts; that is, the number of times the children pushed the ball when presented with the word *push* alone, when added to the number of times the children pushed the ball when presented with the point at ball gesture on its own, was significantly smaller than the number of times the children pushed the ball when presented with the "push" + point at ball combination. In other words, the children needed to experience *both* parts of the gesture + word combination to produce the correct response. Gesture and speech together evoked a different response from the child than either gesture alone or speech alone (see also Kelly, 2001, who found a similar effect in 3- to 5-year-olds).

Role of Gesture in Cognition in the Early Stages of Development

Even before children produce meaningful gestures, they move their hands and, interestingly, those hand movements seem to set the stage for the synchronization between gesture and speech that we see in adult speakers. Couplings between the manual and oral/vocal systems are in place from very early in development (Iverson & Thelen, 1999) A well-established characteristic of systems such as these (known as *coupled oscillators*) is that each tries to draw the other into its characteristic oscillation pattern. Entrainment is said to occur when the activation of one oscillator "pulls in" the activity of the other and yields an ordered patterning of coordinated activity. Iverson and Thelen suggest that entrainment is the driving developmental force behind speech–gesture synchrony.

The evidence comes from a cross-sectional study of 6- to 9-month-old infants in which Iverson and Fagan (2004) found an increase in the coordination of vocalizations with rhythmic *manual* movements (e.g., hand banging, arm swinging), together with a decrease in the coordination of vocalizations with rhythmic *nonmanual* movements (e.g., leg kicking, torso bouncing). In addition, infants were significantly more likely to coordinate vocalizations with single-arm (as opposed to both arms) rhythmic movements, and with right arm (as opposed to left arm) movements, a pattern that presages the predominance of single-handed gestures executed with the right hand in adults. Finally, in most of the infants' vocal-motor coordinations, the onset of the limb or body movement either slightly anticipated or was synchronous with the onset of the vocalization, the temporal pattern found when adults produce gesture along with speech. Although the findings are cross-sectional and need to be replicated with a longitudinal sample, they suggest that, by the time infants reach 9 to 12 months, when first gestures and first words typically appear, the link between manual activity and vocalization is strong, specific, and stable, and available to serve a platform for gesture–speech integration (cf., Butcher & Goldin-Meadow, 2000; Pizzuto, Capobianco, & Devescovi, 2005).

Gesture Precedes Speech

Despite the fact that hand and mouth are integrated early in development, meaningful gestures are produced several months before meaningful words. Beginning around 10 months, children produce gestures that indicate an interest in objects—holding an object up for an adult's inspection, pointing at an object to draw an adult's attention to it, reaching for an object to indicate to an adult that they want it (Bates, 1976; Bates, Benigni, Bretherton, Camaioni & Volterra, 1979). Children often refer to a particular object first using gesture and only after several weeks add the word for that object to their vocabularies. For example, a child might refer to a ball first by pointing at it and only later produce the word *ball.* Children refer to an object for the first time using both modalities relatively rarely, and refer to an object for the first time using speech only even less often (Iverson & Goldin-Meadow, 2005). Gesture may reflect the child's interest in learning the name for a particular object, and as discussed in subsequent sections, it may even pave the way for the child to learn that name.

In addition to pointing gestures, children also produce what McNeill (1992) calls *iconic gestures.* For example, a child might open and close her mouth to represent a fish, or flap her hands to represent a bird (Acredolo & Goodwyn, 1985; Iverson, Capirci, & Caselli, 1994). Unlike a pointing gesture, the form of an iconic gesture captures aspects of its intended referent—its meaning is consequently less dependent on context. These gestures, therefore, have the potential to function like words, and for some children they do (Goodwyn & Acredolo, 1998). Acredolo and Goodwyn (1988) compared the ages at which children first used words and iconic gestures symbolically. They found that the onset of words occurred at the same time as the onset of gestures for only 13 of their 22 children. The other nine children began producing gestural symbols at least 1 month before they began producing verbal symbols—some even began 3 months before. Importantly, none of the children produced verbal symbols before they produced gestural symbols. In other words, none of the children found words easier than gestures, but some did find gestures easier than words.

Not surprisingly, children drop their reliance on symbolic gestures over time. They use fewer gestural symbols once they begin to combine words with other words, whether the language they are learning is English (Acredolo & Goodwyn, 1985, 1988) or Italian (Iverson et al., 1994). There thus appears to be a shift over developmental time: The young child seems to be willing to accept either gestural or verbal symbols; as the child ages, she begins to rely uniquely on verbal symbols (see also Capirci, Contaldo, Caselli, & Volterra, 2005). Namy and Waxman (1998) have found experimental support for this developmental shift. They tried to teach 18- and 26-month-old children novel words and novel gestures. Children at both ages learned the words, but only the *younger* children learned the gestures. The older children had already figured out that words, not gestures, carry the communicative burden in their worlds.

Gesture Predicts Speech

Gesture not only precedes speech, it also predicts changes in speech. Children combine a gesture and a word several months before they combine two words. More to the point, children who are the first to produce gesture + speech combinations in which the gesture conveys one idea and the speech another idea (e.g., point at hat combined with the word *dada* to indicate that the hat belongs to the child's father) are the first to produce two-word sentences conveying the same type of idea ("dada hat"; Goldin-Meadow & Butcher, 2003; Iverson, Capirci, Volterra, & Goldin-Meadow, 2008; Iverson & Goldin-Meadow, 2005; Ozcaliskan & Goldin-Meadow, 2005). Importantly, the type of gesture + speech combination matters—the pattern does *not* hold if we look at the age at which children first produce combinations in which gesture and speech convey essentially the same information (point at hat combined with the word *hat*). Thus, it is the ability to use gesture and speech to convey different components of a proposition (a type of gesture–speech mismatch)—and not just the ability to use gesture and speech in a single utterance—that predicts the onset of two-word utterances (see also Capirci, Iverson, Pizzuto, & Volterra, 1996; Goodwyn & Acredolo, 1998; McEachern & Haynes, 2004).

Gesture thus forecasts the earliest stages of language learning. It might do so because gesture use is an early index of global communicative skill. If so, children who convey a large number of different meanings in their early gestures might be generally verbally facile and, therefore, not only have large vocabularies later in development but also produce relatively complex sentences. Alternatively, particular types of early gesture use could be specifically related to particular aspects of later language use. In fact, we find that gesture *selectively* predicts later language learning. The number of different meanings children convey in gesture at 18 months predicts their spoken vocabulary at 42 months, but the number of gesture–speech combinations they produce at 18 months does not. In contrast, the number of gesture–speech combinations, particularly those conveying sentence-like ideas, children produce at 18 months predicts sentence complexity at 42 months, but the number of meanings they convey in gesture at 18 months does not (Rowe & Goldin-Meadow, 2009a). We can thus predict particular language milestones by watching the particular ways in which children move their hands 2 years earlier.

Gesture Has the Potential to Bring About Change in Language Learning

Gesture has the potential to bring about change in language learning in the same two ways it can influence change at later stages. First, child gesture could elicit verbal responses from parents that are targeted to the child's level. For example, consider a child who does not yet know the word *dog* and refers to the animal by pointing at it. If the mother is attentive to her child's gestures, she is likely to respond, "Yes, that's a dog," thus supplying the child with just the word he is looking for. Or consider a child who points at her father's hat while saying the word "Dada." Her father may reply, "That's Dada's hat," thus translating the child's gesture–speech combination into a simple sentence. Because they are responses to the child's gestures and therefore finely tuned to the child's current state, parental responses of this sort could be particularly effective in teaching children how an idea is expressed in the language they are learning.

Mothers do respond to the gestures their children produce (Golinkoff, 1986; Masur, 1982). For example, mothers frequently translate the gestures that children produce without speech into words, thus providing a verbal label for the object that is on the child's mind at that moment (Goldin-Meadow, Goodrich, Sauer, & Iverson, 2007). In addition, mothers produce relatively long sentences when they respond to their children's combinations in which gesture conveys one idea and speech another (point at hat + "dada")—longer than the sentences they produce when responding to combinations in which gesture and speech convey the same idea (point at hat + "hat"; Goldin-Meadow et al., 2007).

If child gesture is, indeed, playing a communicative role in language learning, mothers' translations ought to be related to later word and sentence learning in their children. In fact, we find evidence for an effect of mother translations on both word and sentence learning (Goldin-Meadow et al., 2007). In terms of learning words, when mothers produce words in response to the gestures that their children produce without speech, children later add those words to their vocabularies. In terms of learning sentences, children whose mothers frequently translate their gestures into speech are first to produce two-word utterances, suggesting that mothers' targeted responses to their children's gestures might be playing a role in helping the children take their first step into multiword combinations. Thus, a child's readiness to learn a word or sentence, as evidenced by the child's gestures, elicits particular responses from parents, which, in turn, facilitate learning in the child.

The second way in which gesture can play an active role in language learning is by giving children repeated opportunities to practice expressing particular ideas before they can express those ideas in speech. Evidence for this hypothesis comes from the fact that early child gesture use is an excellent predictor of later vocabulary size, better than other predictors that have been examined. Rowe, Ozcaliskan, and Goldin-Meadow (2008) videotaped 53 English-speaking parent–child dyads in their homes during their daily activities for 90 minutes every 4 months between children ages 14 and 34 months. At 42 months, children were given the Peabody Picture Vocabulary Test (PPVT). Child gesture use at 14 months (the number of different meanings children expressed in gesture) was a significant predictor of child spoken vocabulary 2½ years later, accounting for a third of the variance. And the relation between early child gesture and later child receptive vocabulary in speech was robust—it held even after the child's speech (number of different words expressed) at 14 months was controlled. Adding parent speech at 14 months and family income to the analysis increased the variance accounted for, but in this model, neither parent speech nor child speech at 14 months was a significant predictor of later child spoken vocabulary. However, child gesture at 14 months continued to be a significant predictor and, indeed, was a more potent predictor than family income. Indeed, child gesture at 14 months has been found to partially explain the differences in vocabulary size that children from low versus high socioeconomic status families bring with them to school (Rowe & Goldin-Meadow, 2009b).

Thus, one of the best predictors of the size of a child's vocabulary at school entry is the number of different meanings the child expresses in gesture at 14 months. It is possible, of course, that the number of different meanings a child expresses in gesture is nothing more than a reflection of the child's interest in communicating. However, it is also possible that the act of expressing these meanings in the manual modality paves the way for future vocabulary development. Future research is needed to decide between these alternatives. We would need to randomly select children and manipulate their gestures early in development, encouraging some to gesture and discouraging others. If the act of gesturing itself contributes to progress in language development, the children who are encouraged to gesture should have larger vocabularies than the children who are discouraged from gesturing.

GESTURING AND LATE ADULT DEVELOPMENT

Spoken language changes in a number of ways in late adulthood. Cross-sectional research suggests that, relative to younger adults (typically between the ages of 18 and 28 years), older adults (between the ages of 70 and 80) typically speak more slowly, are less fluent, produce more clauses with fillers, and make use of shorter, less complex constructions than younger adults, giving the impression that older adults utilize a simplified speech register (see Kemper, 2006, for a review). Differences of this sort have been attributed to age-related declines in a variety of cognitive processes, including working memory and verbal processing.

The best evidence for age-related changes in spoken language comes from a longitudinal study of 30 healthy older adults (Kemper, Thompson, & Marquis, 2001) who were between the ages of 65 and 75 years at the beginning of the study and were seen annually over a period of 7 to 15 years. At each session, an oral language sample (produced in response to elicitation questions such as "describe an unexpected event that happened to you") of at least 50 utterances was collected. Two aspects of speech were tracked over time—grammatical complexity and propositional content (i.e., the informational content of an utterance relative to the number of words)—and declines were apparent in both. The most pronounced decline in grammatical complexity occurred between the ages of 74 and 78, with relatively little change before or after this period. A similar, though less pronounced decline was evident for propositional content, with the greatest change also apparent in the mid-70s. There was, however, considerable individual variability in both initial levels of grammatical complexity and propositional content, and in their relative rates of decline.

Overall, these longitudinal findings suggest that, with age, speech declines in syntactic and informational complexity in at least some individuals. Because, as we have seen, gesture production varies in relation to the content and complexity of its co-occurring speech, we might expect age-related differences in speech to be reflected in older adults' gestures. Surprisingly, however, only a handful of studies to date have examined spontaneous gesture production in older adults and its relation to communication and cognition.

Role of Gesture in Communication During Late Adult Development

A substantial body of evidence suggests that working memory operations are slower in older adults than in younger adults (e.g., Salthouse, 1992). One implication of this age-related slowing is that older adults may experience a disadvantage in spoken language comprehension, particularly when it requires relatively fast processing. Do older adults use gesture to compensate for reduced processing speed?

Thompson (1995) examined whether older adults between the ages of 64 and 85 years use facial articulatory information (visible speech), gestures, or both, when understanding language and whether they rely on this type of information more than younger adults (age range, 17–31 years). Older and younger adults watched and listened to a female speaker videotaped in three conditions: spoken language with facial articulatory movements (visible speech), spoken language with both visible speech and iconic gestures (visible speech + gesture), and spoken language with no view of the speaker at all (speech only). On each trial, the speaker produced a single sentence, which participants were asked to repeat word-for-word immediately after its presentation. Each sentence consisted of 16 words (18–25 syllables); sentences in the visible speech + gesture condition also contained three to four iconic gestures that were, for the most part, redundant with speech. Responses were scored for the number of words correctly repeated, regardless of the order in which they were produced.

Thompson (1995) found that the older adults performed significantly better on sentences in the visible speech condition than in the speech only condition, but the younger adults did not, suggesting that the articulatory cues helped older adults more than younger adults (although the younger adults did well overall, leaving less room for them to improve). Interestingly, adding iconic gestures to visible speech in the visible speech + gesture condition had virtually no effect on older adults' performances but had a significant impact on younger adults' performances: Younger adults performed better on sentences in the visible speech + gesture condition than in either the speech only or visible speech conditions. Thus, although older adults were more influenced by the seeing mouth movements than younger adults, they did not use hand movements as much as younger adults did.

Although this research sheds some light on the extent to which gesture is used during the late adult years when processing spoken language, it is limited in two ways. First, the sentences all contained multiple clauses and were accompanied by three to four iconic gestures, each of which conveyed a distinct meaning. This configuration may have created competition between visible speech and gestures; the sheer amount of additional information conveyed in gestures, combined with more limited processing resources during the late adult years, may have influenced the extent to which older adults were able to attend to and process the gestures. Second, task demands created by the instructions to reproduce the sentences word-for-word may have encouraged the older adults to focus their attention on cues from the mouth and to ignore information from the hand. Although this pattern may not generalize to all communicative situations, it is very clear that whether an older (or younger, for that matter) listener relies on gesture to compensate for difficulties with language processing depends on the listener's task in the communicative context (e.g., to encode the message for verbatim recall vs. to recall the gist of the message).

Role of Gesture in Cognition During Late Adult Development

Two studies to date have attempted to make inferences about age-related cognitive changes by examining older adults' gesture production. In an initial study, Cohen and Borsoi (1996) compared the gestures produced spontaneously by older adults (age range, 62–80 years) versus younger adults (age range, 18–34 years) in a communication-description task to explore whether gesture use increases or decreases with age. On the one hand, given the tight link between speech and gesture, the relatively short descriptions that older adults produce might be accompanied by fewer gestures (assuming, of course, that decline in older adults' verbal skills leads to shorter verbal descriptions relative to younger adults). On the other hand, older adults might use gesture to compensate for poorer verbal abilities, and thus might make greater use of gesture relative to younger adults. In two experiments, groups of older and younger adults (all women) were asked to describe a set of four unfamiliar objects to a video camera. Descriptions were rated by four independent judges for overall quality (on a nine-point scale) and quality of the verbal description (rated with video off). The total number of gestures produced was recorded, and gestures were classified according to whether they were descriptive (i.e., iconic gestures) or nondescriptive (i.e., beats).

Surprisingly, the descriptions produced by older adults were slightly (although not significantly) longer than those of younger adults. Thus, there was no reason to expect differences in the gestures the two groups produced. Nevertheless, in both experiments, older adults used fewer iconic gestures than younger adults; there was no age difference in beat gestures. This result is difficult to interpret without information on the content and complexity of the accompanying speech (which were not analyzed), but it does suggest that separate mechanisms underlie the production of iconic and beat gestures. Cohen and Borsoi (1996) argue that the production of beat gestures is driven by the speech system, whereas the production of iconic gestures is driven by the visual or visuomotor imagery system. They suggest that the apparent decline in iconic gestures in older adults may be driven by an age-related decline in the ability to generate mental images.

Cohen and Borsoi (1996) provide no data in support of a link between iconic gestures and mental imagery, but there is evidence that the two are related. Feyereisen and Havard (1999) assessed the production of representational (including iconic) gestures versus beat gestures in relation to the activation of mental imagery. If production of representational gestures depends on activation of mental images, and if activation of mental imagery declines with age, differences between older and younger adults should be most evident in descriptions of motor actions and/or visual scenes (assumed to elicit images), and less evident in descriptions of abstract, less imageable topics. In addition, the ratio of representational gestures to beat gestures should be positively related to the imagery content of speech.

In this study, older adults (age range, 61–80 years) and younger adults (age range, 18–25 years) were videotaped responding to questions designed to elicit a visual image (e.g., "Could you describe a favorite painting or sculpture?"), a motor image (e.g., "Could you explain how to change the tire on a car?"), or no image (e.g., "What do you think about a single currency in Europe?"). Responses were coded for duration, and speech transcripts were scored for imagery using a computer program that assigns an imagery value (on a seven-point scale) to each word. Participants' responses were then divided into 5-second intervals, and each interval was coded for gestures (occurrence and type). The two primary measures of gesture use were the proportion of intervals containing at least one gesture (a global gesture production score) and the proportions of intervals containing representational gestures versus beat gestures.

Older adults generally produced longer responses and spoke at a slower tempo than younger adults. But there were no age differences for either speech imagery scores or overall gesture production. Furthermore, both groups gestured most in the motor imagery condition, followed by the visual imagery and no image (abstract) conditions, in that order, and both groups produced the greatest number of beat gestures in the abstract condition. Despite these similarities, however, one important age difference was found, and this difference replicated Cohen and Borsoi's (1996) findings—representational gestures were observed less frequently in the older than in the younger adults.

Contrary to Cohen and Borsoi's (1996) hypothesis, however, the absence of age differences in the production of imagery words in Feyereisen and Havard's (1999) data suggests that the decline of representational gestures in older adults is *not* caused by age-related declines in mental imagery. Feyereisen and Havard suggest instead that the infrequent use of representational gestures in older adults is related to differences in the speech styles adopted by older versus younger adults. They note that beats are often associated with metanarrative speech (e.g., repairs, personal comments, provisional clauses), which they suggest is more frequent in older than younger adults. In addition, they suggest that there is a trade-off between beats and representational gestures over the life span such that beats gradually replace iconic gestures as older speakers come to rely more heavily on speech as a primary means of communication. Beats emerge relatively late in children and are initially infrequent. But as linguistic knowledge becomes more sophisticated and more elaborate forms of language are used in communication, beats become increasingly frequent. If there is less demand on gesture to carry the informational load when the verbal message is rich, the increase in beats could bring with it a concomitant decrease in representational gestures. This developmental story rests on two assumptions: that gesture is richest when spoken language is most impoverished, and that older adults have richer spoken language than younger adults. There is currently no evidence in support of either assumption (see Kemper et al., 2001, for evidence against the second assumption).

Although the two studies described in the preceding paragraphs hint at an intriguing developmental phenomenon (i.e., a decline in representational gestures during the late adult years), they raise several issues that will need to be addressed in future research. First, neither study analyzed the speech that co-occurred with gesture so the nature of the reported age differences is unclear. In light of the findings on age-related changes in expressive language described earlier, this is a particularly significant limitation. Second, despite the reported declines in speech complexity and informational content in late adulthood (cf. Kemper et al., 2001), vocabulary size appears to increase consistently into late adulthood (e.g., Schaie & Willis, 1993). Indeed, in both the Cohen and Borsoi (1996) and Feyereisen and Havard (1999) studies, older adult scored higher on vocabulary measures than younger adults.

Finally, although we know relatively little about the ways in which the gesture–speech relation changes in healthy individuals in late adulthood, we know even less about how gesture is affected by the changes in speech that occur in adult disorders such as dementia. The pattern of linguistic decline described in healthy late adult development appears to be accelerated in individuals with dementia, particularly in terms of propositional content (Kemper et al., 2001). There is some indication that, relative to healthy older adults, patients with Alzheimer disease, whose speech is fluent and grammatical but frequently contains circumlocutions and indefinite vague terms, produce more referentially ambiguous gestures (i.e., gestures that are unclear in form or content; Carlomagno, Pandolfi, Marini, Di Iasi, & Cristilli, 2005; Glosser, Wiley, & Barnoski, 1998). Indeed, ambiguous gestures have been found to increase with severity of dementia symptoms (Glosser et al., 1998). But because these studies used relatively small samples and reported extensive individual variability, the effects need to be replicated with larger samples. In particular, longitudinal research is needed to determine whether an increase in ambiguous gestures over time goes hand in hand with a decline in the informational complexity of speech.

WHAT GESTURE TELLS US ABOUT COMMUNICATION DISORDERS OVER THE LIFE SPAN

As previously discussed, the gestures that accompany speech can provide insight into a speaker's underlying thought processes. It is no surprise then that, in children and adults with a variety of language and communication disorders, gesture can provide unique information about the nature and extent of those underlying deficits (see also Capone & McGregor, 2004). This section reviews evidence from a range of disordered populations suggesting that gesture: (1) provides information about diagnostic status and prognostic outcome, (2) reveals subtle language-related deficits that may not be apparent through analyses of speech alone, and (3) provides a means for speakers to compensate for difficulties with spoken language.

Role of Gesture in Diagnosis and Prognosis

A common feature of empirical studies conducted with language-disordered populations is the wide individual variability observed in language and communication skills, even in samples selected on the basis of stringent inclusion criteria. Equally variable are the participants' language outcomes. Thus, for example, some children with autism never acquire any speech, whereas others develop language that is nearly indistinguishable from their typically developing (TD) peers (e.g., Tager-Flusberg, Paul, & Lord, 2005). Similarly, some toddlers with early language delays catch up to their peers by preschool entry, whereas others experience persistent language difficulties (e.g., Ellis & Thal, 2008). In light of this variation, one approach taken by researchers and clinicians has been to, first, identify subgroups of individuals who share a common behavioral profile within a given population, and then examine the extent to which the candidate behavior predicts future language outcomes. Studies of a range of disordered populations across the life span have identified subgroups on the basis of gesture use, and have then examined current and/or future language in relation to subgroup membership.

Children with Early Focal Brain Injury

Children with prenatal or perinatal brain injury exhibit remarkable plasticity in language development, unlike adults (even those with comparable brain injuries), who typically exhibit persistent language difficulties (e.g., Bates & Dick, 2002; Feldman, 2005; Levine, Kraus, Alexander, Suriyakham, & Huttenlocher, 2005; Reilly, Levine, Nass, & Stiles, in press; Stiles, Reilly, Paul, & Moses, 2005; Woods & Teuber, 1978). However, there is great variability across children. Children typically go through an initial, often protracted, period of language delay. This delay resolves for some children but not for others (Bates et al., 1997; Feldman, Holland, Kemp, & Janosky, 1992; Thal et al., 1991; Vicari, Albertoni, Chilosi, Cipriani, Cioni, & Bates, 2002). The variability in outcome across individuals has led researchers to ask whether early gesture can index the likelihood of recovery from initial language delay.

Some indirect evidence on this issue comes from a series of case studies reported by Dall'Oglio and colleagues (Dall'Oglio, Bates, Volterra, Di Capua, & Pezzini, 1994). They described cognitive and language development in six children with early focal brain lesions. Parents completed the Infant form of the Italian version of the Macarthur-Bates Communicative Development Inventory, the *Primo Vocabolario del Bambino* (PVB; Caselli & Casadio, 1995). The PVB includes a list of gestures and actions commonly produced by young children, and parents are asked to indicate the gestures that their child produces. Although these data were not the primary focus of the research, the authors noted that the children who had larger repertoires of gestures and actions also had better language outcomes in their third year.

More recently, Sauer, Levine, and Goldin-Meadow (2010) examined the relation between gesture use at 18 months and vocabulary comprehension at 30 months in a group of 11 children with prenatal or perinatal unilateral brain injury. At 18 months, children were videotaped at home for 90 minutes as they played and interacted with a parent, and all speech and gestures were transcribed from the videos. The primary measures of interest were word types (number of different words, with repetitions excluded) and gesture types (number of unique gesture meanings; pointing gestures used to refer to distinct objects, events, or people were counted as unique meanings). At 30 months, the PPVT-3 was administered to children as a measure of vocabulary comprehension.

Sauer and colleagues (2010) found that the number of different words the children produced at 18 months was not significantly related to PPVT-3 standard scores at 30 months (presumably because the children produced relatively few word types at 18 months). The interesting result, however, is that there was a strong, positive relation between gesture types at 18 months and vocabulary comprehension at 30 months, even after controlling for word types at 18 months. Thus, children who used gesture to communicate a broad array of meanings at 18 months developed vocabularies that were in the normative range 1 year later. In contrast, children who conveyed more limited information in gesture exhibited persistent delays with respect to vocabulary comprehension. These findings suggest that early delays in gesture production can be used to identify those children with unilateral prenatal or perinatal lesions whose language learning is likely to be delayed in the future. If so, we may be able to offer these children interventions while their language-learning trajectory is likely to be most malleable.

Children with Autism

Autism is a neurodevelopmental disorder characterized by impairments in social interaction and communication, and by restricted and repetitive behaviors and interests (American Psychiatric Association, 2000). Atypicality in gesture use is one among several diagnostic indicators of impairment in social interaction and communication. Descriptions of deficits in gesture are present in the classic descriptions of autism (Asperger, 1944/1991; Wing, 1981), and assessment of gestures and their production with speech is an integral component of the gold standard for autism evaluation, the Autism Diagnostic Observation Schedule–Generic (ADOS-G; Lord et al., 2000).

A majority of children with autism exhibit significant language impairment (LI). Indeed, a "delay in, or total lack of, the development of spoken language" is one of the core symptoms in the communication domain (American Psychiatric Association, 2000). However, because many children exhibit delayed language development but are not given a diagnosis of autism (see later), and because gesture impairments are evident in older children and adults with autism, recent work has begun to ask whether the gestures of very young children who eventually receive an autism diagnosis differ from the gestures of TD children. In particular, studies have asked whether there are differences in the gesture forms that are used and the communicative functions those forms serve.

On the surface, this question seems like it should be relatively straightforward to address. But addressing the question empirically has proved to be a challenge. Because an autism diagnosis involves impairment in a variety of domains that typically develop only over the first 2 to 3 years (e.g., language, symbolic play, peer relationships), it is difficult to make a reliable diagnosis of autism before age 2 (e.g., see Rogers, 2001). Indeed, many children with autism do not receive a diagnosis until they enter a school setting (e.g., Mandell, Novak, & Zubritsky, 2005). As a result, it is difficult to collect data on the early development of gestures. In addition, because the prevalence rate of autism in the general population is approximately 1:150 (Wing & Potter, 2002), an impossibly large sample of children would be needed to provide longitudinal data on what would end up being a very small number of children ultimately diagnosed with autism.

In light of these difficulties, one strategy that researchers have used is the retrospective analysis of home videos of children with autism. In this approach, parents of children with an autism diagnosis are asked to provide videotapes made during the child's infancy (e.g., at a first birthday party). These videos are then transcribed and coded for the child's use of gestures. Studies taking this approach have consistently reported differences in the gestures produced by children who are later diagnosed with autism compared with the gestures observed in videos collected from parents of TD infants under comparable conditions.

One of the most widely cited investigations of this sort compared videos recorded at the first birthday parties of 11 children later diagnosed with autism with those of 11 TD children (Osterling & Dawson, 1994). The first birthday party was assumed to provide a context for assessing early social communication that would be fairly similar across children. Results of this comparison suggest that, relative to TD infants, infants subsequently diagnosed with autism produced fewer gestures overall and almost no instances of pointing. This latter finding has been confirmed by a number of other researchers (e.g., Bernabei, Camaioni, & Levi, 1998), leading some to suggest that failure to point by 12 months may be a red flag for autism (Filipek et al., 2000).

Retrospective home video studies have also reported that the relatively infrequent use of gestures observed at 12 months in children later diagnosed with autism is characteristic of the entire 12- to 24-month period (Adrien et al., 1992). Indeed, between 12 and 18 months, the gap in gesture production between TD children and children with autism appears to widen substantially, with gesture production continuing to increase in TD children but remaining relatively flat in children later diagnosed with autism, a pattern that may be specific to autism (Crais, Watson, Baranek, & Reznick, 2006).

In addition to differences in frequency of gesture use, children later diagnosed with autism demonstrate a more restricted repertoire of gestures, and use gestures for a more limited range of communicative functions, than do TD children. Thus, for example, in a study that compared home videos of 9- to 12-month-old children who eventually received an autism diagnosis with home videos of children who were developing along a typical trajectory, Colgan and colleagues (2006) reported that 60% of the autism group (compared with only 29% of the TD group) failed to use any "social interaction" gestures (conventional/ representational gestures such as "shake head no," "wave," "so big"), and when they did use these gestures, the gestures were significantly less varied than those of the TD children. In addition, in a recent study, Clifford and Dissanayake (2008) compared home video observations of children later receiving an autism diagnosis with those of TD children across two age ranges: 12 to 18 months and 18 to 24 months. The initiation of joint attention (involving the deictic gestures point and show, among other behaviors) did not vary by group in the early period. However, by 18 to 24 months, TD toddlers used gesture to initiate joint attention four times more often than the group with autism. This finding is consistent with frequent reports in the literature that, although older children with autism use gesture to request objects or events and do so at rates that are roughly comparable with those of TD peers, they rarely use gesture to establish shared attention or to comment on a particular object of interest (e.g., Buitelaar, van Engeland, de Kogel, de Vries, & van Hooff, 1991; Wetherby, Yonclas, & Bryan, 1989).

The retrospective home video methodology has provided valuable insight into the nature and development of gesture in very young children later diagnosed with autism. However, the technique does have a number of serious limitations (e.g., inadvertent sampling bias introduced by parents in deciding when to video, substantial variation in amount of footage available for individual children, atypicality of contexts such as the first birthday party). Researchers have, as a result, turned to prospective longitudinal study of infant behavior in an attempt to observe indices of a later autism diagnosis as they occur. To circumvent the need for an unmanageably large general population sample to obtain even a small sample of children receiving an eventual autism diagnosis (given the low incidence of autism in the general population), investigators have recruited samples from a high-risk population, namely, the younger, infant siblings of older children already diagnosed with autism. The probability of receiving a diagnosis of autism is approximately 200 to 300 times higher in younger siblings of children diagnosed with autism (hereafter *infant siblings*) than in the TD population (e.g., Ritvo et al., 1989). This approach has two significant advantages: (1) It significantly increases the chances of studying children who will eventually receive an autism diagnosis (approximately 18–20% of infant siblings eventually receive an autism diagnosis; Yirmiya, Gamliel, Shaked, & Sigman, 2007; Zwaigenbaum et al., 2005); and (2) it permits the design of prospective, longitudinal studies in which behaviors can be assessed in contexts and for periods that are consistent across participants.

Longitudinal work with infant siblings suggests that gesture may be a potentially useful indicator of risk for a future autism diagnosis. For example, in a parent report study using the MacArthur-Bates Communicative Development Inventory (Fenson et al., 1993), infant siblings later diagnosed with autism had significantly smaller gesture repertoires at 12 and 18 months than infant siblings who did not eventually receive such a diagnosis and than a comparison group of infants with no family history of autism. What is especially noteworthy about this finding is that, before the age of 18 months, gesture was more informative about future diagnostic status than word comprehension or production. Differences between infant siblings later diagnosed with autism and the two comparison groups did not emerge in speech until 18 months of age (Mitchell et al., 2006).

Recent research making use of direct behavioral observation during home visits has reported results consistent with these parent-report data. In a longitudinal study of 21 infant siblings, Iverson and colleagues (Iverson, Poulos-Hopkins, Winder, & Wozniak, 2008) reported that, at 13 and 18 months, three children subsequently diagnosed with autism were at the very bottom of the distribution on all measures of deictic gesture production. Specifically, they produced few gestures overall, and the few gestures they did produce were primarily giving and reaching (i.e., gestures that serve a requesting function), rather than pointing and showing (i.e., gestures that are more likely to involve the establishment of joint attention; see also Parladé, Koterba, & Iverson, 2009).

Additional work is, of course, needed to establish gesture use (or its lack) as a specific marker of autism (as opposed to a general marker of language and communication delay independent of cause). Nevertheless, current evidence indicates that the relative lack of gesture production and, in particular, the virtual absence of pointing and infrequent use of gestures to initiate joint attention is a highly sensitive index of autism. Indeed, failure to point may be a hallmark of autism in very young children. Importantly, because these differences may be evident as early as 12 months, well before the period when language delay becomes apparent, gesture impairment may be of particular value as a source of information about diagnostic risk for autism in very young children.

Late-Talking Toddlers

"Late talkers" are young children who exhibit delays in expressive language in the absence of hearing loss, mental retardation, behavioral disturbances, or other known forms of neurological impairment. Data from prevalence studies indicate that approximately 15% to 19% of 2-year-olds are delayed in expressive language, defined as having a vocabulary of fewer than 50 words or no productive two-word combinations, or both (e.g., Klee, Pearce, & Carson, 2000; Rescorla, 1989). For some children, this early delay is transient, with language abilities appearing to "catch up" by about age 3. For others, however, initial delays persist and may be an indicator of a more significant LI. This pattern suggests that early language delay may stem from a variety of different factors, ranging from difficulties with oral articulation to difficulties with symbolic communication (e.g., Rescorla & Merrin, 1998). Thus, the question of prognostic indicators has become a critical issue for diagnosticians and clinicians attempting to identify appropriate interventions for late talkers.

In a series of studies, Thal and colleagues have provided evidence that gesture may be one such indicator. They have demonstrated that gesture production can distinguish between children who are late bloomers (i.e., children who recover from initial delays and begin to produce age-appropriate language) and those who remain delayed. In an initial study (Thal & Bates, 1988), 18- to 32-month-old late talkers (all still in the one-word stage of language development) were presented with two tasks: (1) a single gesture imitation task in which children imitated object-related gestures produced by an experimenter (e.g., drinking from a cup, making a toy airplane fly); and (2) a gesture-sequencing task in which children were asked to reproduce a series of familiar, scripted actions modeled by an experimenter (e.g., feeding a teddy bear by putting him in a highchair, putting on his bib, feeding him an apple, and wiping his mouth). Each late talker was individually matched to two TD comparison children: one on the basis of expressive vocabulary size (language-matched control subject), and one on the basis of sex and age (age-matched control subject). Thal, Tobias, and Morrison (1991) examined these children 1 year later to determine whether any of the measures from the initial observation reliably predicted language outcome. At the follow-up visit, 6 of the 10 late talkers were classified as *late bloomers;* they had caught up and had language skills comparable with the skills of TD peers. The remaining four children continued to exhibit language delay and were classified as *truly delayed.* Two measures from the initial visit distinguished between the late bloomers and the truly delayed children: Truly delayed children were delayed in comprehension (as measured by parent inventory and an experimenter-administered picture identification task) and also performed significantly worse than late bloomers on all gesture task measures. Taken together, these findings suggest that vocabulary comprehension measures, combined with the imitation of conventional object-related gestures embedded in familiar scripts, provide valuable prognostic information about recovery from early language delay.

Although gesture production on an experimental imitation task can distinguish among subgroups of late talkers, the measure provides little information about how late talkers use gesture to communicate and whether spontaneous gesture can be used for diagnosis. Thal and Tobias (1992) addressed this issue by analyzing communicative gestures in a new cohort of 18- to 28-month-old late talkers, all in the one-word stage, and a group of younger, language-matched comparison children participating in a series of structured play sessions. Relative to language-matched control subjects, late talkers used significantly more communicative gestures, particularly as answers to adult questions. Moreover, late talkers who were eventually identified as late bloomers produced significantly more communicative gestures at the initial visit than late talkers who were eventually identified as truly delayed. The truly delayed children used only as many gestures as their language-matched control subjects.

On the basis of these data, Thal and Tobias (1992) suggest that late bloomers are using gesture to compensate for their delay in oral language, whereas truly delayed children do not. They speculate that the relatively low frequency of communicative gesture in truly delayed children reflects more substantial difficulties with language (e.g., deficiencies in symbolic representation and in recognizing that symbols can have communicative value). That late bloomers made extensive use of gesture suggests that symbolic abilities and a desire to communicate are in place in these children. Their delayed language production may therefore be a product of difficulties in word retrieval and production, articulatory problems, or other temporary obstacles to language, rather than a symbolic or communicative deficit. The findings also underscore the role that gesture can play as an assessment tool in evaluating toddlers suspected of language delay. Gesture can provide information about the nature, severity, and prognosis of the delay not readily accessible in evaluations of language alone.

Adults with Aphasia

One frequently occurring and widely recognized adult syndrome, Broca's aphasia, is of particular interest in the study of gesture and speech because it provides the opportunity to examine the relation between these two systems after damage to areas of the brain known to be involved in language production. The speech of individuals with Broca's aphasia is often referred to as nonfluent, and is marked by incomplete and syntactically simplified sentences, reduced phrase length, awkward articulation, and disturbances in the rate, stress, pitch, and intonation of speech (e.g., Kearns, 2005). For example, an adult with Broca's aphasia might attempt to describe how to use a cup by saying "cocoa…a…a…uh soup…coffee." Models that posit a tightly linked, integrated system between gesture and speech would predict that, in the presence of a language breakdown of this sort, gesture ought to break down as well, displaying characteristics parallel to halting speech (e.g., McNeill, 1992, 2005).

Although only a handful of studies have examined gesture production in adults diagnosed with Broca's aphasia, this prediction has generally been confirmed. For example, relative to adults with Wernicke's aphasia (who typically produce fluent but semantically empty speech) and healthy adults, adults with Broca's aphasia produce fewer gestures overall (presumably reflecting their limited speech output). When they do gesture, adults with Broca's aphasia use more iconic and fewer beat gestures, and a greater proportion of gestures in the absence of speech compared with adults with Wernicke's aphasia and healthy adults (Cicone, Wapner, Foldi, Zurif, & Gardner, 1979; Glosser, Wiener, & Kaplan, 1986; Pedelty, 1987). The findings suggest that language and gesture break down in parallel. Just as the speech of adults with Broca's aphasia is characterized by short utterances filled with content words, and lacking function words and grammatical markers, so are their gestures more likely to convey substantive information (i.e., iconics) rather than mark the rhythm of fluent speech (i.e., beats).

One limitation of these findings, however, is that they are based on observations taken at a single point in time in adults who vary widely in the amount of time that has passed since the onset of their symptoms (from weeks to years). Although the adult brain exhibits less plasticity in the face of injury than the child brain, language abilities often exhibit measurable recovery over time in adults with aphasia (Cappa et al., 1997; Kertesz, Harlock, & Coates, 1979). This observation raises two questions: (1) How does gesture change as language recovers, and (2) can gesture predict the likelihood of language recovery?

Braddock (2007) addressed both questions by following a group of six men with Broca's aphasia over the first 6 months after the onset of their symptoms. The initial observation was completed approximately 4 to 8 weeks after symptoms appeared (usually caused by stroke), with five additional monthly follow-up visits. At each observation, adults completed an object description task. All speech and gestures produced in this task were transcribed and coded, and compared with speech and gesture in a group of men with no neurological impairment matched on age and education. In addition, at the initial and 6-month visits, the Western Aphasia Battery (Kertesz, 1982) was administered to assess change in language abilities.

As a group, the adults with aphasia demonstrated significant improvement in verbal communication over the 6-month recovery period (although their verbal skills remained significantly below those of the comparison adults throughout the period of study). With regard to whether these verbal improvements were accompanied by changes in gesture, the data provide a mixed picture. At the initial observation, adults with aphasia gestured at a significantly higher rate than the comparison group; indeed, the distributions of the two groups were almost completely non-overlapping. Six months later, however, this difference had decreased substantially, primarily because of a decrease in the gestures the aphasia group produced with speech. There was no change in how often the aphasic group used gesture without speech (15% and 12% of their communications at the initial and 6-month follow-up visits, respectively, consisted of gestures without speech, compared with none for the comparison group), and no change in the types of gestures the aphasic group used (the majority of their gestures at the initial and 6-month follow-up visits were emblems, whereas the comparison group primarily used iconic gestures).

Although these group-level patterns are intriguing, there was also considerable variability among individual adults with aphasia on both measures. The sample size was too small to allow for statistical analysis of differences. Nevertheless, there was a natural split in the distribution of gesture rates within the aphasia group at Time 1: three adults fell above and three fell below the median (high vs. low gesturers, respectively). The high gesturers produced shorter utterances and fewer different words across the 6-month period than the low gesturers. Indeed, there was a remarkably high correlation between gesture rate at the initial observation and utterance rate at the 6-month follow-up examination ($r = -0.87$; $p = 0.015$) in the aphasic group. In short, although adults in both subgroups exhibited comparable levels of difficulty with spoken language immediately after the onset of their aphasic symptoms, the adults who made the most extensive use of gesture initially were also the adults most likely to have *poor* language outcomes after 6 months of recovery.

Overall, the findings suggest that, as language abilities recover, gesture changes, and that gesture assessed within the first months after aphasia onset may be a useful clinical indicator of the extent to which language abilities can be expected to recover. Adults who present initially with comparable profiles of language abilities and impairments may, in fact, vary widely in prognosis. Paradoxically, an initial pattern of compensation via gesture may not be a positive prognostic indicator for language recovery. Unlike children, for whom early gesture use is a sign of resilience and an indicator that they may *not* be delayed in the future, adults with aphasia who gesture may expect worse outcomes than adults who do not gesture. Although replication of these findings with a larger sample is clearly needed, the results suggest the importance of including systematic assessments of gesture in evaluations of adults with aphasia.

Gesture as a Window Onto the Nature of Language Deficits

Just as gesture can provide a window onto speakers' underlying thought processes, so, too, can it yield unique information about the nature of the language deficits exhibited by individuals with communication disorders. Findings from two set of studies, one focused on individuals with Down syndrome (DS) and one on individuals with Williams syndrome (WS), suggest that variation in patterns of gesture use can offer insight into the nature of language difficulties that are not readily apparent in analyses of speech alone.

In keeping with the nature of the cognitive impairments characteristic of DS, young children with DS exhibit significant delays in early language development (e.g., Chapman & Hesketh, 2000). Recent research, however, suggests that young children with DS exhibit an additional cognitive delay over and above the delay evident in their level of language use, a delay that is apparent only when their gesture-word combinations are taken into account. Iverson and her colleagues (Iverson, Longobardi, & Caselli, 2003) observed the spontaneous communication of five children with DS (age range, 37–53 months; mental age range, 18–27 months) as they played with their mothers, and individually matched them to TD children on number of different words (i.e., vocabulary types) produced during a 30-minute play session.

When children were matched on vocabulary types, no significant differences between groups were found for total number of words, gestures, or gesture-word combinations produced (i.e., tokens). However, the two groups did differ in the types of gesture-word combinations they produced. The TD children produced a relatively large number of supplementary combinations in which gesture conveys different information from the information conveyed in speech (e.g., "dada" + point at hat). In addition, in line with previous findings reviewed earlier indicating that supplementary combinations herald the onset of two-word speech (e.g., Capirci et al., 1996; Goldin-Meadow & Butcher, 2003; Iverson & Goldin-Meadow, 2005; Pizzuto et al., 2005), three of the TD children were already producing a small number of two-word utterances. In contrast, the children with DS produced almost no supplementary combinations and no two-word combinations. Thus, in addition to the well-documented global delay in language, children with DS appear to exhibit an additional, specific delay in the ability to combine two ideas within a single communicative act (either two words or a word plus a gesture).

WS is a genetic disorder that has captured particular attention because individuals with WS exhibit an unusual pattern of strengths and weaknesses across domains (e.g., very poor visuospatial processing with relatively intact face recognition; Bellugi, Lichtenberger, Jones, Lai, & St. George, 2000). Although language has traditionally been thought to be relatively "spared" in WS (but see Karmiloff-Smith et al., 1997; Volterra, Capirci, Pezzini, Sabbadini, & Vicari, 1996), recent research suggests that here, too, individuals with WS exhibit a profile of varying strengths and weaknesses. Thus, for example, although individuals with WS are generally reported to have rich vocabularies and fluent speech in everyday conversational interactions, performance on laboratory-based tasks requiring rapid picture naming is relatively poor (Rossen, Klima, Bellugi, Bihrle, & Jones, 1997; Stevens & Karmiloff-Smith, 1997; Vicari, Carlesimo, Brizzolara, & Pezzini, 1996).

In an attempt to clarify the nature of the picture-naming impairment in WS, Bello, Capirci, and Volterra (2004) examined gestures produced during a picture-naming task (the Boston Naming Test) in school-aged children with WS and two groups of TD children: one matched to the WS children on chronological age and the other on mental age. Because speakers often use iconic gestures when they are having difficulty retrieving particular lexical items (Krauss, Chen, & Gottesman, 2000), the researchers reasoned that gesture production during naming might provide insight into the nature of the picture-naming impairment in WS. The children with WS were found to produce comparable numbers of correct and incorrect naming responses, and to make similar types of errors as the mental age-matched comparison TD children, suggesting that semantic representations may not be impaired in children with WS. However, the children with WS took more than twice as long to name the pictures as the children in both of the TD comparison groups. Furthermore, the children with WS were more likely to report that they could not remember the names of the pictures, to exhibit uncertainty about their responses, to produce irrelevant speech (e.g., "What's that?") before providing a naming response, and to accompany their spoken responses with iconic gesture. Indeed, children with WS not only produced iconic gestures together with their verbal circumlocutions (a pattern found in the TD children as well), they also produced gestures together with their correct responses and when they failed to respond at all (which the TD children did not do). Taken together, these differences suggest that, despite a relatively high level of accuracy in picture naming, children with WS do experience difficulty in the process of lexical retrieval.

In summary, differences in how gesture is used in relation to speech in young children with DS point to a specific delay in packaging two distinct ideas within a single communicative act, and in children with WS point to impairments in the processes underlying lexical retrieval. Both findings underscore the importance of including gesture together with speech in assessments of disordered language systems.

Gesture as a Compensatory Device

When speech is difficult, gesture can serve as an alternate communicative route, compensating for limited oral language and providing a more complete picture of the speaker's knowledge than the view seen in speech on its own. Studies of children with DS and children with specific language impairment (SLI) offer cases in point.

As described earlier, children with DS generally have expressive language abilities that are less advanced than their cognitive skills. They might, therefore, be able to use gesture to compensate for their linguistic difficulties. Research based on parent reports of child gesture use (e.g., the Macarthur-Bates Communicative Development Inventory; Fenson et al., 1993) has generally supported this prediction; relative to TD children, children with DS were reported by their parents to have enhanced gestural repertoires (Caselli, Vicari, Longobardi, Lami, Pizzoli, & Stella, 1998; Singer Harris, Bellugi, Bates, Jones, & Rossen, 1997). However, studies of spontaneous communication have failed to find a "gesture advantage" in children with DS (Chan & Iacono, 2001; Iverson et al., 2003).

Laboratory research on somewhat older children has also reported compensatory use of gesture in individuals with DS. Stefanini, Caselli, and Volterra (2007) examined speech and gesture produced during picture naming in children with DS (ranging in age from 3 years 8 months to 8 years 3 months) and in two groups of TD children individually matched to the DS sample on the basis of developmental and chronological age, respectively. For each picture, the child's spoken response was classified as correct, incorrect, or a failure to respond. During picture presentation, all gestures, whether produced with or without speech, were transcribed and coded by type (deictic, iconic, and other, including beat and conventional). Each overall response was then classified as unimodal (speech alone or gesture alone) or bimodal (containing both speech and gesture). All bimodal responses containing iconic gestures were then further examined to determine whether the gesture expressed a meaning similar to or different from the expected target word.

Relative to both TD comparison groups, children with DS produced a significantly greater number of incorrect spoken answers and failures to respond. There were also reliable group differences in overall gesture production, with children with DS producing more iconic (but not deictic or other) gestures than children in either of the TD comparison groups. Indeed, children with DS produced nearly twice as many iconic gestures as children in the developmental age-matched group and three times as many as their same-aged peers. Consistent with their increased use of iconic gesture, children with DS were also significantly more likely than TD children to produce bimodal or unimodal gestural responses to the pictures and, importantly, to use those iconic gestures to convey "correct" information about the picture that was lacking in their speech. This difference was so substantial that when naming accuracy was recoded to include not only correct spoken responses but also iconic gestures that conveyed meanings similar to those of the target words, naming accuracy for children with DS increased dramatically (although it remained below accuracy for both comparison groups).

The fact that children with DS can convey correct information in their gestures that is not evident in their speech suggests that using speech alone to assess their knowledge may substantially underestimate that knowledge. It also underscores the fact that their ability to represent the meaning of a picture exceeds their capacity to link meaning with speech. Along these lines, Capone (2007) has suggested that if a child's meaning representation is intact but is poorly linked to phonological representation, the meaning representation may be readily expressed in gesture.

Unlike children with DS who have known cognitive deficits, children with SLI have no identifiable intellectual impairments yet fail to acquire age-appropriate language skills. Although the language of children with SLI has been extensively characterized (e.g., Leonard, 1998), relatively little attention has been devoted to their gestures. However, two studies to date, one with preschoolers and one with older children, suggest that children with SLI do use gesture, that they use it to compensate for poor oral language, and that their gestures often convey information that is not found in their speech.

Iverson and Braddock (2009) examined speech and gesture on two picture narration tasks in preschoolers with LI and in age- and sex-matched TD peers. As anticipated, the language of the children with LI was significantly less advanced across a variety of measures than the language of their TD peers. Strikingly, however, the children with LI produced significantly more gestures per utterance than the TD children. Moreover, for children with LI (but not for the TD children), gesture rate was negatively correlated with expressive language ability (indexed by a composite measure derived from spontaneous speech). In other words, in the LI group, the poorer the child's language, the higher that child's gesture rate.

In a study of older children with SLI, Evans, Alibali, and McNeil (2001; see also Mainela Arnold, Evans, & Alibali, 2006) gave children a series of Piagetian conservation tasks and compared their performance with a group of chronologically younger TD children matched to the children with SLI on number of correct conservation judgments. The children with SLI did not use gesture more often than the judgment-matched TD children. However, they were significantly more likely to express information in their explanations that could *only* be found in gesture. For example, when given a water conservation task, a child with SLI might express the essential components of a conserving explanation—the fact that the tall container is not only taller than the short container but is also thinner (i.e., the two dimensions compensate for one another)—by indicating the height of the container in speech and its width in gesture. When Evans and colleagues considered the spoken and gestured components of children's explanations together, children with SLI were found to produce significantly more conserving explanations than the judgment-matched comparison children. It is not surprising that the children with SLI knew more about conservation than their task-matched peers—they were, after all, older than the comparison group. What is of interest is the fact that *all* of the additional knowledge that the children with SLIs displayed was expressed uniquely in gesture and not in speech.

In summary, just as gesture can "fill in" when speech is difficult in unimpaired speakers (e.g., McNeill, 1992), so, too, can it be used by speakers with language disorders to compensate for poor oral language. Notably, however, the gestures produced with atypical language do not form a substitute system that replaces speech. The gestures produced by individuals with disordered language appear no different from the gestures that any speaker produces with speech. Speakers with atypical language appear to utilize the gesture-speech system that all speakers use, but they may do so more frequently to compensate for language difficulties.

GESTURING ACROSS THE LIFE SPAN

We have seen that speakers of all ages gesture when they talk. Moreover, gesturing appears to play the same roles throughout development. The gestures that speakers produce play an important role in communication, often conveying information that the speaker does not convey in her words. And listeners pay attention to those gestures (albeit not necessarily consciously), often changing the way they respond to a speaker as a function of her gestures. Even young children are able to glean meaning from gesture, seamlessly integrating it into the meaning that they glean from speech. Gesture is part of the conversation, regardless of whether we acknowledge it.

Gesture is also part of our cognition. At the least, the gestures that a speaker produces reflect the speaker's thoughts—at times, thoughts that the speaker does not (and perhaps cannot) express in speech. But there is mounting evidence that the gesture does more than reflect a speaker's knowledge. It can play a role in changing that knowledge; in other words, it can play a role in the learning process itself. Does the role of gesture in cognition change over time? Proficient language users, like beginning language learners, convey information in gesture that is different from the information conveyed in speech and often do so when describing tasks that they are on the verge of mastering. However, the learning task facing the young child is language itself. When gesture is used in these early stages, it is used as an assist into the linguistic system, substituting for words that the child has not yet acquired. But once the basics of language have been mastered, children are free to use gesture for other purposes—in particular, to help them grapple with new ideas in other cognitive domains, ideas that are often not easily translated into a single lexical item. As a result, although gesture conveys ideas that do not fit neatly into speech throughout development, there may be a transition in the kinds of ideas that gesture conveys as children become proficient language users. Initially, children use gesture as a substitute for the words they cannot yet express. Later, once they master language and other learning tasks present themselves, they use gesture to express more global ideas that do not fit neatly into wordlike units. Future work is needed to determine when this transition takes place.

Because gesture reflects thought, it can be used by researchers, parents, teachers, and clinicians as a window onto the child's mind, a window that provides a perspective that is often different from the perspective that speech provides. Early delays in gesture production can be used to identify children whose language learning is likely to go awry in the future, allowing clinicians to identify children likely to have persistent language difficulties well before those difficulties appear in speech. One of the interesting differences that we see in gesturing over the life span is the role it plays in compensating for language disabilities. Young children who are suffering from language delays and who gesture to compensate for those impairments have an excellent prognosis, better than the prognosis for children who have language delays and do not gesture. In contrast, adults who are suffering from aphasia and who gesture to compensate for their language losses appear to have a worse prognosis than adults who have aphasia and do not gesture. Thus, although gesture appears to play the same kind of role in communication and cognition throughout development in healthy individuals, it may take on different roles over the life span in individuals suffering from LIs. The interesting question for future research is why?

Finally, because gesture has the potential to change thought, it can be used in the home, the classroom, and the clinic to alter the pace, and perhaps the course, of learning and development. We have good evidence that gesturing can change the course of learning in school-aged children. Future work is needed to determine whether gesturing can be used to influence learning in the early and late stages in the life span. If we find that gesture is causally involved in change throughout the life span, its effect is likely to be widespread. As we have seen throughout this chapter, gesture is pervasive and, as listeners, we pay attention to gesture even though we typically do not realize that we are doing so. The time seems ripe for researchers to notice gesture, too, looking beyond speakers' words to the thoughts held in their hands.

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